AN ANALYSIS OF A COURSE OF LECTURES ON THE PRINCIPLES OF NATURAL PHILOSOPHY,

By C. H. WILKINSON, *Surgeon*, *k*
OF THE
SOCIETY OF ARTS,
MEMBER OF THE PHILOSOPHICAL SOCIETY
OF
MANCHESTER,
AND
LECTURER ON EXPERIMENTAL PHILOSOPHY
AT
St. BARTHOLOMEW's HOSPITAL.

TO WHICH IS PREFIXED,

AN ESSAY ON ELECTRICITY,

WITH A VIEW OF EXPLAINING THE PHENOMENA OF THE LEYDEN PHIAL, ETC. ON MECHANICAL PRINCIPLES.

London:
PRINTED FOR M. ALLEN, 15, PATERNOSTER-ROW.
1799.

TO

BENJAMIN COUNT OF RUMFORD,

F. R. S. M. R. I. A. &c.

THE FOLLOWING

ANALYSIS

OF A

COURSE OF LECTURES

ON

NATURAL PHILOSOPHY,

AS DELIVERED BY THE AUTHOR,

IS MOST RESPECTFULLY INSCRIBED.

No. 10, Leicester-Street,
Leicester-Square.

ERRATA.

Page 79. l. 3. ON THE, read OF THE.
—— 80. l. 3. *produce*, read *produces*.
—— 85. l. 11. *Animal*, read *Mineral*.
—— 94. l. 14. *Bongouer*, read *Bougouer*.
——105. l. 27. *exerts*, read *exert*.
——109. l. 15. *Tripolium*, read *Trifolium*.
—— Do. l. 16. *Lichen vertrillalus*, read *verticillatus*.
——122. l. 19. *meniscus glass*, read *as a watch glass*.
——122. last l. *plane convex*, read *plano-convex*.
——133. l. 13. *Lieberkulen*, read *Lieberkuhn*.
Ditto l. 20. Ditto Ditto.
——164. l. 7. *infringes*, read *impinges*.
——168. l. 7. *Schenchzer*, read *Scheuchzer*.
——195. l. 12. *says*, read *say*.

ADVERTISEMENT.

MEDICAL ELECTRICITY.

THE benefical effects which have been experienced by the application of Electricity in a variety of diseases, render it necessary for every practitioner to medicinally examine this pervading principle.

As the knowledge of this branch of philosophy is yet in its infancy, it requires the united observations of many individuals before its influence on our organization can be well ascertained. Every complaint in which

which it may be advantageously employed should be accurately characterised, and its effect in every stage of the disease carefully stated.

With such a professional consideration, Mr. WILKINSON, Surgeon, has fitted up at his House, N° 10, *Leicester-Street, Leicester-Square*, an appropriate and extensive Apparatus: by employing Electricity on so large a scale, he flatters himself he shall hereafter be enabled to make some useful inferences.

Every Case he purposes accurately to mark down, to observe the stated periods when any effects are induced, the degree of power employed, and the requisite time for its application particularised.

To accommodate those who prefer the administration of Electricity at their own houses,

houſes, Mr. W. has arranged a number of portable electric Machines, which he equally ſuperintends.

TERMS FOR ATTENDANCE.

To be electrified every Day at the Medico-electrical Rooms, one Guinea per Week. To be accommodated with an Apparatus at their own houſes, and there attended daily, two Guineas per Week.

AN

AN ESSAY

ON

ELECTRICITY.

AS Thales confidered motion and mind as one and the fame principle, we can no longer be furprifed, that the wonderful power of the magnet and of the amber fhould be deemed by him the effects of animation: as if the foul of the *electron* or *amber*, roufed into action by rubbing, drew into its embrace light furrounding fubftances, that when the power ceafed, it ceafed, becaufe the vital portion funk into repofe.

So long as this idea was entertained, no farther inveftigations were made refpecting the real caufe, or whether fuch a power exifted in other bodies, excepting the lyncurium or toumaline, mentioned by Theophraftus, till the period of Dr. Gilbert,

 of

of Colchester: to particularise the various discoveries of successive philosophers, would be foreign to the intention of this little Essay, and unnecessary, as the history of this science has been so ably executed by the learned Dr. Priestley.

My intention in the following pages is to endeavour to explain the phenomena of electricity on mechanical principles, to regard electricity as a fluid subject to laws common to all other elastic fluids, and to render unnecessary the use of the terms attraction and repulsion *, to which no clear or distinct ideas can be annexed.

* In some Philosophical Essays I published a few months since, I have there fully expressed my opinion respecting the existence of powers possessing the properties of *attraction* and *repulsion*. All the experiments which have been adduced in support of such a supposition, I presume I have there explained on principles purely mechanical. My intention was to have pursued the same mode of inquiry in electricity, gravitation, magnetism, and chemical affinities. As my avocations will not allow of my paying proper attention to the three latter subjects, the investigation of these I shall defer a few months longer.

Electricity

Electricity in a Fluid ſui Generis, or diſtinct from any other.

Electricity is a fluid diſtinct in its properties from light, caloric, and magnetiſm.

That it is not ſimilar to light, Beccaria obſerved that electricity was not luminous when paſſing through a nearly exhauſted tube. Many experimentaliſts had remarked, that in a well-prepared barometrical tube there was no light produced by the agitation of the included mercury againſt the ſides of the Torricellian glaſs. Mr. W. Morgan has demonſtrated the truth of this by a well-arranged experiment.

When light appears attendant on the fluid, it is elicited from the bodies through which the electricity paſſes.

That it is not ſimilar to caloric is evident from its not being abſorbed and given out by bodies in proportion to their ſpecific gravities, to its velocity being ſo infinitely ſuperior to that of caloric, to its inflaming ſpirits of wine, which caloric will not*, and to its action on bodies not being univerſal, while that of caloric is.

That

* A red heated body, immerſed in ſpirits of wine, will not inflame them. Flame and caloric are in many reſpects different;

That it is not ſimilar to magnetiſm, as the direction of the fluids is not only different, but the magnetic fluid is limited to iron, while all metals and almoſt all fluids are ſubject to the action of electricity.

Conductors and Non-Conductors.

Mr. Gray caſually diſcovering that ſilk would not conduct electricity, was led by this circumſtance to make experiments with other ſubſtances; hence bodies have been divided into two claſſes, *Electrics per ſe*, and *Non-Electrics*. When Franklin, by ſome experiments, was induced to ſuppoſe that electricity was equally diffuſed through all ſubſtances, he changed the terms of *Electric per ſe* into *Non-Conductors*, and Non-Electrics into Conductors.

Some experiments which I have made induce me to believe that bodies poſſeſs different degrees of electricity: that the moſt perfect conductor poſſeſſes the largeſt quantity of electricity, and

ent; a ſmall flame will diſcharge a Leyden phial at twice the diſtance a very conſiderable heated body will. Flame will not fire gunpowder. The expanſive power of flame is very conſiderable; a ſmall portion of ſpirits of turpentine falling gradually on a heated body, the force of the flame gives motion now to a very powerful machine.

the

the moſt perfect non-conductor the leaſt quantity.

It is a circumſtance well known to electricians, that in a tube exhauſted about 100 times, very ſmall portions of electricity are viſible, from the reſiſtance of the air being conſiderably diminiſhed, become more diffuſed, and paſs through a larger ſpace.

In a glaſs receiver, about ſix inches in diameter, and fourteen long, I made a quick revolution of a cuſhion, which communicated by a braſs rod to the top of the receiver, and made it rub on a piece of plate glaſs fixed on a ſtand, elevated to about the centre of the receiver; the corruſcations were very vivid. When the braſs rod was removed, and the cuſhion was left inſulated, the light produced was very faint. When a ball of ſealing wax was rubbed on the glaſs, there was no light evident. When glaſs plates inſulated were rubbed on each other, there was no luminous appearance.

When quickſilver was forced through wood by the preſſure of the atmoſphere, and the ſmall mercurial particles daſhed on the ſides of an included glaſs receiver, by ſuch an action electricity was produced *.

* This experiment was firſt made by Hawkſbee; he called it a mercurial phoſphoreal light, and has ſince been commonly repeated. The experiment will not ſucceed, unleſs in a ſmall receiver, that the exhauſtion may be rapid.

From

From theſe circumſtances, I am induced to ſuppoſe, that the facility with which electricity paſſes through ſome bodies is in the ratio of the quantity they contain, and the reſiſtance to its progreſs in the inverſe proportion.

Suppoſing A B, Fig. I. to be a tube filled with air, if I force a column of air equal to the column A a, it will paſs on eaſily, and the quantity will go out of the tube. If, inſtead of ſuch a tube A B, I make uſe of a tube C D, divided by a number of partitions, in vain ſhould I attempt to force in a quantity equal to a column C d, becauſe the different partitions would prevent its acting on the air in the whole tube; thus its admiſſion or paſſage would be prevented.

The ſame mode of reaſoning may be eaſily transferred to conductors and non-conductors. Suppoſing A B a metallic rod replete with electricity, any ſucceſſive portions of electricity will only have to overcome the gentle reſiſtance of the fluid within the rod, and hence eaſily tranſmitted. When a body contains little or no electricity, not being enabled to overcome the reſiſtance of the intervening ſpaces, it would be ſimilar to the partitions of the tube C D.

We may compare conductors to water diffuſed through the vaſcular ramifications* of a ſponge, which,

* Vaſcular ramifications of a ſponge.—When a fine ſection of a piece of ſponge is powerfully magnified, it appears like a congeries

which, when preſſed on any part, an adequate portion of fluid will be exuded from all around, while non-conductors are more analogous to a wet lock of cotton, there being not that continuity in the reſpective portions, ſo that any force partially induced would not influence the whole.

When we receive a ſpark from a conductor, this ſpark is not identically the ſame fluid produced from the rubber by its attrition on the cylinder, but the quantum of electricity previouſly inherent in the conductor, and drove forwards by the juſt produced quantity.

The Denſity on the Conductor will neceſſarily be equal to that on the Cylinder.

This may be illuſtrated by an analogy to air. Air, we know, would be expanded to a conſiderable extent, if there were not a general equalization; thus air, included in a ſquare glaſs bottle, acts on the internal ſurface of the glaſs with a force equal to 15lb. on every ſquare inch, a force more than ſufficient to overcome the reſiſt-

congeries of exquiſitely fine veſſels; and it is owing to ſuch tubular conſtruction the power of abſorbing and retaining ſo much water.

ance

ance of the glaſs. As the external ſurface of the glaſs is alſo ſurrounded by an equivalent force, they counteract each other; if we abſtract the circumambient air, the included elaſtic fluid evinces its power by burſting through its vitreous priſon.

So electricity, diffuſed through different bodies, is preſerved quiet, by the reſiſtance to its egreſs being in an exact ſtate of equalization; when this equality is deſtroyed, it then manifeſts itſelf in proportion to its power.

Air holding in ſolution a quantity of water, becomes a conductor in proportion to the quantity it contains; thus in very wet weather it is difficult to perform electrical experiments, then there being very little reſiſtance to the electrical fluid equalizing itſelf, ſo that any accumulation is prevented.

When the air is dry, the reſiſtance to the electric fluid is in proportion to its denſity; as action and re-action are equal, the electrical fluid equally acts on the air, and can only be accumulated to ſuch a degree till it is equal to the reſiſtance of the air. When beyond this, the reſiſtance is overcome, and the equalization reſtored; thus air condenſed, by reſiſting more will likewiſe admit of a larger accumulation of electricity; when rarefied, reſiſts leſs, and is overcome by a ſmaller quantity.

If

If air was a conductor, no electrical experiments could be performed; there could be no accumulation in the one part, no deficiency in another: we ſhould be deprived of all thoſe advantages which we derive from atmoſpherical electricity. This principle would then not have entered into combination with water, when converted by ſolar rays into vapour, and when having paſſed through its aërial circulation, it would no longer be precipitated with thoſe portions ſo conducive to vegetation; there would have been a dull uniformity in the atmoſpheric region, and Nature would thus have been deprived of one of her moſt energizing agents. While, on the contrary, we ſee by this wiſe proviſion, that no action takes place without unfolding a portion of this enlivening principle. The evaporation of a drop of water, as well as the concourſe of floating fields of vapour, elicit, in their diſturbance, more or leſs electricity: to this ſhowers owe their genial power, by falling on plants, on the ſurface of the earth, containing different proportions of electricity; the equalization produces that action which ſtimulates and excites vegetable life.

The Effects of Electricity on suspended Pith Balls.

It is well known to electricians, that an excited glass tube, or a stick of sealing wax, applied near suspended pith balls, will make them diverge. When they are rendered diverging by the excited glass tube, which, if removed, and an excited resinous body applied, the separation between the balls is destroyed, and they are brought into the state they were in before they were disturbed. If both the excited bodies should be applied to the pith balls at one and the same time, there will be no sensible action induced; their states being different, they counteract each other. Du Faye, who first observed this, supposed there were two different kinds of electricity, contrary to each other; the one he termed vitreous, and the other resinous. As these states appeared to Dr. Franklin to be entirely owing to the bodies having more or less than their natural quantity, he changed the terms, as before observed, to positive and negative.

In order to explain the phenomena of the balls, it has been assumed as an axiom, that electricity of

of a ſimilar nature repel each other; and of a contrary nature attract each other. When the pith balls ſeparate, they are ſaid to repel each other.—How vague and indefinite is the word repulſion; can we conceive that matter can act beyond where it really exiſts, that it ſhould have a power of influencing other bodies ſituated remote; not only this, but we are alſo told, that there are ſuch bodies, whoſe own conſtituent particles are ſo inimical to each other, as to have a continual niſus of receding. If ſuch were really the caſe, there would not be exiſting in Nature two homogeneous particles in a ſtate of union. Some ſay the grand principle of repulſion is fire; while Lavoiſier ſuppoſes that it is actuated by a powerful principle of attraction, and having a violent tendency to unite forced-aſunder particles of other bodies.

We are too apt to aſcribe to matter, whoſe exility eludes our ſenſes, powers incomprehenſible to us. If we ſee, from their effects, they have a tendency to ſeparate, we fancy that it is the reſult of a repulſive power circumſcribing the body; if we ſee them approximating, we ſay they are ſurrounded with an attractive power. Such a mode of reaſoning is unphiloſophical—it is explaining "*ignotum per ignotius.*" For the preſent let us wave all theſe refinements, and let us regard the electric fire as amenable to the ſame laws with common matter.

If

If we conſider it as ſimilar to other elaſtic fluids, all the phenomena of electricity may be eaſily explained.

If the pith balls were placed in a medium perfectly rare, no divergency would be induced by the application of any excited ſubſtance; as they are ſurrounded by a medium which reſiſts the tendency to equalization, it is ſuch reſiſtance which produces the ſeparation.

This reſiſtance is very evident in the experiment of the electric fly; the electricity pouring forth from the points in order to equalize itſelf, meets with reſiſtance in the ſurrounding air; the re-action of this medium produces the retrogade motion. When this fly is placed in an exhauſted receiver, there is no ſuch motion induced.

When a glaſs tube is excited, with reſpect to the elaſticity on its ſurface, it is in a ſtate of exceſs, and is termed poſitive. When applied to the inſulated braſs rod A B, Fig. II. the exceſs, meeting with a conducting ſubſtance, enters into it, until the braſs rod and the excited glaſs are equal; in this caſe the braſs rod has more than its natural quantity, and conſequently endeavours to equalize itſelf with the ſurrounding air. As the air is but a very imperfect conductor, the tranſmiſſion of it is very ſlow; the pith balls a b communicating with the braſs rod, are likewiſe in a poſitive ſtate of electricity; the exceſs they pour out from every point radiating from all around the

the balls: the resistance to the evolution of this fluid, from the surrounding air, is the greatest in the plate of air which lies between the two balls. Supposing e f, Fig. II. to represent the plate of air, the air must remain stationary, from being equally acted on by equal quantities of electricity, proceeding from a and b in opposite directions, and consequently counteracting each other; the plate of air thus acted on by the two balls reacts on them; and it is this re-action which causes them to separate.

When an excited resinous body, or stick of sealing wax, is applied, with respect to electricity, it is in a state of deficiency, and consequently the electricity existing in conducting bodies will flow towards it, in order to equalize itself. In this state, when applied to the insulated rod, the rod will give out a part of its natural quantity to equalize itself with the resinous body; the pith balls will necessarily be equally negative, and will separate in the same manner as when positive. In this case they possess less electricity than what is necessary to balance the electricity of the surrounding air, which, in equalizing itself, will gradually impart streams of electricity towards the balls in a converging manner. The plate of air between the two balls will be imparting electricity in equal quantities to them both, in opposite directions, and by thus counteracting each other render the plate of air stationary; while

the pith balls, ſeparate from the impulſe of the fluid, added to the re-action; as the impulſes all around the balls are exactly equal, excepting the portions between each ball having an additional re-action, which drives them into contrary directions.

In the poſitive ſtate of electricity, the ſuperabundant portion diffuſing itſelf all around, will be thrown off the ball a and b, in the direction of the dotted lines. In this caſe we ſee there is no portion of air acted on by the electricity from both balls, but the portion e f, which lies between them.

So in the negative ſtate of electricity, the air, in equalizing itſelf with the balls, will give out its exceſs in the direction of the dotted lines, converging towards the balls. As every particle which is given out will neceſſarily re-act on the air, the ſame as a cannon recoils from the re-action of the ball, no portion of air ſurrounding the balls can reſiſt this re-action ſo much as the plate of air e f. The re-action from the electricity given out to the ball a, cannot make the portion of air recede, becauſe there is the ſame re-action from the electricity given out to the ball b; hence the balls a and b meeting with greater reſiſtance from the intervening plate of air, will neceſſarily recede.

The

The Effects of Attrition on Glass.

Glafs, in its natural ftate, contains little or no electricity. As we have already fhewn, that a powerful rubbing action of two plates of glafs would not elicit a fingle particle of electricity; when rubbed by a fubftance that is replete with it, at the inftant of attrition, when under the immediate contact of the rubber, it becomes, in the rubbing point, a conductor, which being in a comparative ftate of deficiency with the rubber, the electricity of the rubber pours forth, in order to equalize itfelf with this new-formed conducting part. This ftate has only a momentary exiftence, and the powers of conducting die the inftant the glafs is difengaged from the rubber; hence it is that the portion of electricity, which is difengaged from the rubber, loads the air which furrounds the glafs with a fuperabundant portion, and, obedient to the general law of fluids, will pafs where it meets with the leaft refiftance. If in this ftate it fhould be applied to an infulated, conducting body, it will equalize itfelf immediately with this fubftance. When we excite a plate

plate of glaſs with a rubber on one ſide, pith balls are no ways agitated by being applied to a part of the glaſs directly oppoſite to the rubber; the moment this part is diſengaged from the rubber, then the direct oppoſite portion will diſturb the pith balls with that ſtate of electricity neceſſarily reverſe to itſelf.

Thus in an electrical machine we muſt not ſuppoſe that the electricity is forced or *pumped out*, as it is ſometimes expreſſed, from the rubber, by the mere mechanical action of attrition; an inſulated braſs cylinder, by the moſt powerful rubbing, may be moved to eternity without diſengaging a ſingle particle of electricity; the portion of glaſs which is under the immediate contact of the rubber becoming a conductor, equalize itſelf with the rubber, by abſtracting a portion of its electricity, the ſame as when a bladder, half filled with air, remains in this ſtate, becauſe its denſity is equal to that of the ſurrounding medium. If the denſity of the circumambient air be diminiſhed, no longer a counteracting force to the included air, this will expand itſelf till it becomes an exact balance to the fluid around.

In order that every part of the glaſs paſſing under the rubber may be excited, it is neceſſary that it ſhould be equally preſſed; that this contact may be affected, an unctuous amalgam

gam* is equally ſpread upon the cuſhion, preciſely upon thoſe parts immediately acted upon by the glaſs; alſo, by being of a metallic nature, is an excellent conductor, and forms that chain of connection, ſo as to allow of the electricity to immediately equalize itſelf.

The ſilk added by Dr. Nooth is a very conſiderable improvement; although the air is a bad conductor, yet if the ſpace between the rubber and the prime conductor is conſiderable, a great portion of electricity would be diſſipated. As ſilk is a non-conductor, much more reſiſts the electricity than the ſurrounding air, great care ſhould be taken that the ſilk be ſo arranged, that the moment the glaſs is diſengaged from the rubber, it ſhould be directly under the contact of the ſilk. If there ſhould be the interval of a quarter of an inch, the electricity would return by theſe to the rubber again, and thus we ſhould loſe the greateſt part.

It is from an accurate attention to theſe circumſtances that the plate machines of Mr. Cuth-

* Baron Kienmier's amalgam is an excellent preparation: three ounces of quickſilver, two ounces of tin, and one ounce of zinc; the quickſilver put into a wooden box, chalked, the tin and zinc melted, and poured upon the quickſilver; immediately agitate the whole together, they will all be united. This amalgam muſt be finely powdered and ſifted through a piece of cambric, or other fine ſubſtance, and mixed with a ſufficient quantity of hog's lard, till brought into the conſiſtence of being eaſily ſpread.

bertſon's are ſo ſuperior in their power to any of a cylindrical form; ſo much ſo, that in the ratio of their ſurface they produce double the effect of the cylinder; every part being more perfectly under the action of the rubber, is rendered in a more perfect conducting ſtate, and conſequently will abſtract a greater quantity of electricity from the cuſhion. When the glaſs is diſengaged from the cuſhion, the electricity will be thus ſuperiorly accumulated; in equalizing itſelf with the prime conductor, it will impart a ſuperior quantity; ſo that when a phial is charged, the inſide of the phial, the prime conductor, and the cylinder, have equal intenſities of electricity, ſo that the ſuperior the intenſity of the plate, the higher the phial can be charged.

On this principle we may eaſily explain the reaſon why a ſmall cylinder or plate, with its proper-ſized rubber, will not produce the ſame quantity of electricity as the ſame-ſized rubber on a larger cylinder or plate, although ſo revolved that equal ſurfaces ſhall be rubbed in equal times. Let us ſuppoſe the circumference of the ſmaller cylinder or plate be thirty inches, and that of the larger ſixty inches; in order then that the ſurfaces rubbed in equal times may be equal, there muſt be two revolutions of the ſmaller to one of the larger; ſo that every inch of one machine is rubbed twice to every inch of the other; the ſame time is not allowed to every diſtinct portion

tion of the rubbed ſurface to be reſtored to that ſtate as to admit of the greateſt degree of excitement.

What may be this peculiar change induced in glaſs by the action of rubbing, may be difficult to conceive. I have ſometimes been induced to ſuppoſe that this may, in ſome reſpect, depend on an alteration in the temperature of the glaſs, while under the immediate action of rubbing. When glaſs is much warmed, we know it then becomes a conductor; that electricity permeates it as eaſily as it does a metallic body. Let us indulge in this hypotheſis, and ſee how, by ſuch a ſuppoſition, we may explain the above circumſtance.

If the glaſs immediately under the action of the rubber ſhould poſſeſs at that time ten degrees more temperature than any other part of the glaſs, in proportion to this increaſe, it will be enabled to abſtract more electricity from the cuſhion. When diſengaged from the cuſhion, the increaſe of temperature immediately diminiſhes, and conſequently gives out the electricity. When the ſurface of the glaſs is ſmall, every part paſſes ſo quick under the rubber, that the difference between the temperature under the rubber, and the other parts of the glaſs, becomes leſs, and hence leſs quantities of electricity produced than when there is a larger ſurface. If it were poſſible to have all the parts of the glaſs twenty or thirty degrees colder than the parts immediately under

the cuſhion, we moſt probably ſhould accumulate electricity to an amazing intenſity*.

There would be no difficulty in working a machine in a large receiver, filled with oxygen gas, or hydrogenous gas, as theſe gaſes contain great quantities of caloric; from ſuch experiments ſome uſeful deductions might be made.

A reſinous body, when excited, becomes not only a conductor at the moment of excitement, but retains the power a certain time afterwards; ſo that every ſubſtance with which it can come into contact of a conducting nature, or containing electricity, it will abſtract ſo much, till it becomes in a ſtate of equalization; thus it is why, in a ſtate reverſe to the glaſs, the glaſs gives it out, but the reſinous body ſtill coninues to abſtract; hence, when acting together, the reſinous body readily admitting what the vitreous body is giving out, they appear to counteract each other.

Perhaps this power of retention in reſinous bodies may be dependant on the ſame ſtate requiſite for combuſtibility.

* *Query.* Whether a ſmall bottle cylinder would not be more excited if filled with quickſilver, ſo that, by being in contact with ſo denſe a medium, its temperature would be more equalized?

THE LEYDEN PHIAL.

Dr. Franklin's Theory.

IN leſs than two years after the diſcovery of the Leyden Phial, Dr. Franklin endeavoured to explain the cauſe on the principle of poſitive and negative electricity. He ſuppoſed twenty particles of electricity on the inſide, and the ſame quantity on the outſide; when one particle was added to the inſide, it repelled a particle from the outſide; ſo that when the quantity withinſide was doubled, the whole on the outſide was expelled.

To this theory many objections have been made. Glaſs, according to Dr. Franklin, is not permeable to electricity, and yet is replete with it. By what power could any additional quantity within expel the ſame quantity from without, and yet no ways pervading the glaſs?

To

To the ſupport of this theory Dr. Franklin ſays the electric matter repels itſelf, and attracts all other matter.

When, to the ſupport of any theory, we are under the neceſſity of attempting to explain any action by the terms *repulſion* and *attraction*, ſuch is a confeſſion of our entire ignorance. If we wiſh to convey to another clear and diſtinct ideas about certain operations in nature, ſurely we would not make uſe of a mode of reaſoning ſtill more intricate than the ſubject of our inveſtigation. Nature, beautifully ſimple in all her operations, purſues not that mazy path which the cloudy genius of an Ariſtotle trod. Occult qualities and myſterious powers are no more ſcience than boiſterous epithets and turgid declamation are true eloquence. Even when the great Des Cartes produced his plain and rational theory, yet, with a prejudice almoſt national, the great mind of a Newton evinced its fallibility, by ſtill retaining Ariſtotelian abſurdities.

Even in Newton we find many expreſſions which his moſt powerful advocates cannot unfold; and yet how many there are who receive his conjectures as ſacred myſteries, and attribute their incomprehenſion to an intellectual inability, as if their eyes were blinded by that reſplendent blaze of truth upon which his eagle ſight could gaze without injury.

In

In the firſt point of view, the Franklinian theory appears ſimple and eaſy; when more minutely examined, it is found attended with inſuperable difficulties. A power of a body extending beyond the body itſelf, influencing other bodies without any material agency: an *actio in diſtans* is too wild a theory to be admitted, and is no ways ſupported by any analogy in nature. Some of its advocates ſay, that "flame will communicate heat through ſubſtances which are impervious to the flame itſelf." What is flame but the rapid decompoſition of caloric from oxygen gas: hence the caloric may be tranſmitted to a body, without that body being alſo enabled to produce the ſame quick decompoſition. A body muſt be heated to a certain intenſity before it can acquire this power *.

Another

* We might ſuppoſe, that to every particle of oxygen there is a particle of fire; that an equalization is preſerved ſo long as there is no diſturbance: acted upon all around, they equally react, and thus preſerve the balance. When any change is induced in a body, by any proceſs or diſturbance whatever, and by ſuch a change there ſhould be leſs reſiſtance to the oxygen particles in that direction than to any other, the union between theſe particles and thoſe of caloric will be deſtroyed exactly in that part where the reſiſtance is the leaſt that is in contact with the body; ſo that the caloric will be thrown upon the body, while the oxygen particles are in union with the body. If this proceſs ſhould be ſlow and gradual, as in metallic bodies, it will be calcination or oxydation. If the proceſs ſhould be rapid, the rapid ſeparation of caloric would form a fiery atmoſphere

Another argument that has been advanced, is an experiment with three equal-ſized balls. If theſe three balls are ſuſpended on three ſtrings, one elevated, and the other two balls in contact, when the elevated ball is ſet at liberty, it will act upon the ſecond ball, and the ſecond ball on the third. In this experiment, it is ſaid that the third ball is the only one which moves; the ſecond receives the impulſe from the firſt, and tranſmits the whole of the impulſe to the third, without being itſelf any ways diſturbed.

The ſame mode of reaſoning has been applied to the Leyden Phial; that the electricity accumulated on the inſide may act on the glaſs, and the glaſs, by acting on the electricity on the outſide, thus force it away.

Although this is the caſe in the congreſs of bodies, ſuch can no ways explain why there ſhould be no accumulation within, unleſs the electricity on the outſide can be conducted away.

phere about the body where expoſed to the air, and conſtitute a flame: thus the flame of a candle is preſerved in its direction from being ſo ſpecifically lighter than the ſurrounding medium, although the decompoſition is all around. The inſtant a particle is ſeparated, the very ſame inſtant it riſes up in that direction where it meets with the leaſt reſiſtance; thus all accumulating, form a cylindrical flame round the combuſtible body, and which becomes conical in that part where detached. To purſue theſe inquiries, we might eaſily explain not only the different coloured tints of the ſame flame, but alſo the different intenſities in the different parts.

Mr. Morgan has attempted to remove these difficulties, by supposing the electric fluid exists as a component part of the glass, and retained there by a strong attractive power, as he is under the necessity of supposing different degrees of attraction existing in different parts of the glass. As attraction is the basis of his system, its reality ought to be previously demonstrated, before any dependence can be placed on the superstructure.

Du Faye's Theory of the Two Electricities.

The difficulties attending the Franklinian system, respecting the impermeability of glass, induced Messrs. Eeles, Symner, Atwood, and others, to adopt the idea of Du Faye, of there being two distinct kinds of electricities; with this difference, Du Faye supposed the electricities existed naturally different in different bodies, while these gentlemen suppose, that the two electricities are always united, and only evince their power when separated; that when in union they counteract each other, so as in this state are perfectly tranquil. When they are divided, they each have uncontrolled their separate power; and their strong attractive nisus to unite, is the cause of every electrical appearance.

By thus regarding electricity as a compound of two distinct principles, which, when divided, will permeate glass, they thus attempt to explain the Leyden Phial.

These two principles they term, after Du Faye, the vitreous and resinous electricity; and farther assume, that similar electricities repel each other, and contrary electricities attract.

By the action of the rubber on the cylinder, the electricities of the rubber are decomposed; that the vitreous portion is separated and given to the cylinder, and takes back as much resinous electricity; the cylinder gives out the vitreous portion it has just received to the conductor, and receives back an adequate portion of resinous electricity; the conductor imparts this vitreous portion to the inside of the Leyden jar, and takes back its resinous portion; this additional vitreous portion repels the vitreous portion from the outside, while the resinous portion on the outside is attracted within. At this period there is no electricity on the outside, but what is uncombined; hence, with rapidity, will attract the opposite electricity, when it meets with no resistance *.

If simplicity is an argument in favour of any system, such cannot be advanced in favour of

* The experiments adduced by Mr. Atwood, in his learned Analysis, in favour of there being two electricities, will hereafter be considered.

this;

this; ſo complicated a doctrine, and ſo contrary to every other chemical operation, that it need only to be heard to carry with it a conviction of its improbability. We are firſt to ſuppoſe, that by the mechanical action of the cylinder rubbing on the cuſhion, that the electricities are decompoſed and exchanged between theſe two bodies. If we ſuppoſe ſuch an action could induce ſuch a change in this part, how is the diſturbance to take place on the conductor? Electricities which ſo ſtrongly attract each other to be ſo eaſily ſeparated, and thoſe portions remaining which actually repel each other, is a chemical inconſiſtency beyond our powers of comprehenſion. If I diſengage carbonic acid from an alkali by means of the citric or oxalic acid, could it be ſuppoſed that the laſt union could be itſelf decompoſed by carbonic acid gas? If this were true, what would become of our doctrines of affinity?

Mr. Read endeavours to explain the phenomena of atmoſpherical electricity, by ſuppoſing, that wherever poſitive electricity exiſts, it muſt induce a correſponding negative ſtate; and that when the attraction of theſe two electricities is greater than the reſiſting medium, they rapidly unite, and at the point of union are inactive; to this he attributes the dark ſpot we ſee in every ſpark. If Mr. Read is not an advocate for the doctrine of the two electricities, as he has previouſly given his opinion that there is only one *elec-*

tric fluid, I cannot comprehend what is meant by the *attraction of a negative body.*

To this gentleman the philoſophical world is much indebted for his accurate meteorological obſervations. As an individual, I ſhould heartily join in the general wiſh, that he would perſevere in what he has ſo ably begun.

In the year 1791, an Eſſay appeared, not very philoſophically written, under the name of a Dr. Peart, in terms rather illiberally reprobating the advocates of the Franklinian ſyſtem. With a peculiar *modeſty* this gentleman ſays, that " *his principles and his theory alone can rationally explain the phenomena of electricity, which never will be underſtood unleſs they be admitted**." If Dr. Peart means that the ſcience of electricity will be to us unknown till his principles are underſtood, then indeed it would be for ever incomprehenſible. Ether and phlogiſton are words caſually caught hold of, without any relation to the original ſignification of the words. Theſe, he ſays, " are the active principles which produce the phenomena of magnetiſm, electricity, gravitation, chemical affinities, light, fire, which he *gazes* at with admiration." It is unneceſſary making any comments on a ſyſtem ſo incoherent as this.

* Dr. Peart on Electricity, p. 87.

Rev. Mr. Bennet's Syſtem.

In an elegant little production on electricity, Mr. Bennet ſuppoſes electricity may be a mixed fluid, and that one of the component parts is ſufficiently ſubtile to permeate glaſs. This decompoſition Mr. B. ſuppoſes may be effected by condenſation; that when, by the action of the machine, the electricity is accumulated in a phial, as the accumulation increaſes, the fluid, by occupying leſs ſpace, is condenſed, ſo that the portion which can permeate glaſs is forced through, and, by uniting with the ſurrounding electricity, would rarefy it, like heat diffuſed amongſt colder bodies.

This ſubtile fluid Mr. Bennet ſuppoſes may be a modification of light.

If ſuch were the caſe with electricity, how ſhould we be enabled to explain the impoſſibility of charging a phial when inſulated.

Monf. De Luc's Theory.

Volta fuggefting an analogy between electric fluid and watery vapours, upon this Monf. De Luc has endeavoured to form a fyftem: he fuppofes, that if a plate of glafs was equally moift with water on both fides, and on one fide a quantity of fteam was thrown, the fteam would be condenfed on that fide, and increafe the quantity of water, while the fire, with which it was united, will pafs through the glafs, and, uniting with the moifture on the other fide, convert it into vapour; fo that while the water on one fide was accumulating, that on the other fide would be diminifhing*. Thus he fuppofes the electric fluid to be compofed of two fubftances; one ca-

* Je fuppofe une lame de verre, à la température des corps environnans, & tapiffée *d'ean* des deux côtés. Je fuppofe de plus, que des *vapeurs aqueufes*, plus chandes que cette lame, fe portent à une de fes faces, que je nommerai A. A méfure que ces vapeurs arrivent au contact de la lame, il s'en décompofe une partie; le *feu latent* libéré, fe répand dans toute la lame, & l'eau abandonnée fe joint à celle dont la face A étoit déjà tapiffée. Le nouveau *feu* qui arrive à l'autre face, B, y produit l'effet contraire à l'égard de la quantité d'*eau*; car il augmente l'evaporation fur cette face; ce qui y diminue cette quantité. *J. A. De Luc Idées fur la Météorologie.*

pable

pable of permeating glaſs, and which he calls *fluide déférent électriqae*; the other not ſo ſubtile, and which he names *la matière électrique*; and that when theſe are thrown on one ſide, the deferent fluid pervades the glaſs, uniting with the natural quantity on the ſurface, paſſes off through the leaſt reſiſting conductor.

To this theory there are the ſame objections as to Mr. Bennet's; and moreover, the analogy here is not very correct; for ſteam thrown on the plate of glaſs, arranged as he deſcribes, would not produce the effect mentioned.

Theory of the Editors of the Encyclopedia Britannica.

In this work the identity of *fire, light,* and *electricity* is endeavoured to be proved; that when light is intercepted by any opake body, and reflected, heat is produced; and from an experiment of the incorrect Monſ. Achard, they deduce, that heat in ſummer becomes electric fluid in winter. Cold is by theſe gentlemen rendered a poſitive body, and the reſult of a quieſcent ſtate of the ſame fluid; and yet, in this tranquillity, preſſes on the ſurfaces of bodies and contracts them.

them. When this fluid diverges from a centre, it operates as heat, and then expands bodies. When it proceeds in ſtraight and parallel lines, it acts as light; but in this caſe it is only heat when converged; in a *quieſcent active* ſtate it is cold; and when in a ſtate which I do not comprehend, it produces all the phenomena of electricity.

The electric fluid thus prepared, they ſay, when it meets with an electric ſubſtance, produces a vibratory motion; when with conducting ſubſtances, a progreſſive one: thus in every charged phial there is a violent impulſe or vibration of the fluid outward from the poſitive, and inward to the negative ſide. The preſſure of the poſitive ſide, in diſcharging, yields to the preſſure of the negative ſide, and runs along the conductor; when it approaches the negative ſide of the bottle, meeting with more of the ſame kind, the current of which is directed the ſame way, both together break through the air with a violent flaſh and crack, and all appearances of electricity ceaſe.

The firſt principles which are here aſſumed reſpecting the vibratory and progreſſive motions, are too hypothetical to be admitted; and even if theſe were granted, the ſubſequent reaſoning is a tiſſue of unphiloſophical deductions. A ſyſtem ſo wild is not congenial to the uſual accuracy of Edinburgh writers. The part devoted to this ſcience ſeems to have been undertaken by one

who

who is neither a theoretical nor practical electrician; and who, by collecting a number of ſcattered remarks, has given them in that deranged manner they appear in this work.

All the theories heretofore mentioned require as data principles which can no ways be granted; to make uſe of the words *attraction* and *repulſion*, is no more than ſaying that the inſide of a Leyden Phial can be charged when the outſide communicates with the cuſhion or the earth. When it is aſſumed, that electricity is a fluid compoſed of two principles which are decompoſed by any mechanical action, we have no illuſtrative analogy in nature.

In the ſubſequent attempt to explain the phenomena of electricity on mechanical principles, I have diveſted myſelf of terms which imply the exiſtence of myſterious powers. I regard electricity as a fluid amenable to the ſame laws as all other matter that is cognizable to our ſenſes. The theory I now ſubmit to the Public is the reſult of a variety of experiments; and any thing I have aſſumed as a datum, I hope the reaſons I have advanced will prove ſatisfactory.

A NEW THEORY

OF

THE LEYDEN PHIAL.

AIR, pure and unmixed, poſſeſſes little or no electricity; in ſuch a ſtate it would form one of the beſt non-conductors. This is a ſtate in which it never naturally exiſts; it holds in ſolution more or leſs water, and as this is a conducting medium, replete with electricity, the non-conducting power of air is deſtroyed in proportion to the quantity of water with which it is united.

Let us ſuppoſe A B, Fig. 3, to repreſent a ſmall column of particles of air and electricity; the circles to repreſent particles of air, and the triangles particles of electricity. In this caſe we ſee the columns ſo equally divided, that there are four particles of air between two particles of electricity,

electricity: In this ſtate they perfectly equalize each other, and ſo long as undiſturbed remain tranquil; as if it were a tube filled with water, communicating with a bladder replete with the ſame fluid; ſo long as the reſiſtance in the tube is equal to that in the bladder, there would be an equilibrium; if the balance ſhould any ways be deſtroyed, and no change whatever could be induced without altering the counteracting powers, the difference of ſtates would appear till a reſtoration takes place.

So with this aërial column; a particle of electricity added to the particle 1, neareſt to B, cannot be added but by changing the relative ſituation of the aërial particles. The particles of air contiguous to the additional portion of electricity will have the reſiſtance of two particles on one end, and only one particle on the other. The particles of air cannot diſplace the ſingle particle of electricity without overcoming the reſiſtance of the ſecond portion of aërial particles; ſo that in an elaſtic fluid like air, the particles in the firſt column will be more compreſſed than thoſe in the ſecond; and the ſecond more than the third; and the third more than the fourth; ſo that the approximation of the aërial particles, in conſequence of the electrical addition, will be in the inverſe cubic ratio of their diſtances from the freſh-added electricity.

If a conducting ſubſtance, a medium replete with electricity, and through which the electric particles meet with very little reſiſtance, be applied to the accumulated particles at B, there will be leſs reſiſtance in paſſing through the conducting body than acting againſt the particles of air.

When no ſuch conducting ſubſtance is applied, the air is agitated, is not only evident from the electrical thermometer, but alſo when the broad end of an egg ſhell, with the pellicle forming a bladder of air, lies within an inch of the circuit of a large battery, and during the diſcharge, ſwells and burſts, and which demonſtrates an expanſion of the air.

The quantum of electricity in the atmoſphere, added to the reſiſtance of the aërial particles, is always a counterbalance to the large quantity diffuſed through conducting ſubſtances. When, from any circumſtance, a larger quantity ſhould be thrown into the conducting ſubſtances, columns of electrical particles will cauſe the air to recede, there will be as many columnar lines as there are points on its ſurface; the diſtance to which it forces the air marks what is called the electrical atmoſphere.

Thus in whatever place electricity is accumulated, it is accumulated by diſpoſſeſſing the air of its

its ſituation; owing to this circumſtance is the formation of fairy rings and water ſpouts*.

* Fairy rings.—In Nottinghamſhire and the adjacent countries are frequently ſeen burnt annular marks on the graſs, about four or five yards in diameter; the ſoil about theſe parts is obſerved to be richer, and funguſes abound there. The country people imagine they are formed by the glowing feet of the little fairies dancing in a ring: this is explicable on electrical principles. All the phenomena of atmoſpherical electricity depends upon the different aërial portions; from a variety of circumſtances, there may be one portion of air containing more or leſs electricity than another; in equalizing themſelves, they diſplace the intervening portions of air, and the phenomena of thunder and lightning enſues; immediately after the report, a wind is always obſerved to move towards that place. If the diſtance between two clouds ſhould be greater than the ſum of the diſtances from each cloud to the earth, the earth, as a conducting body, will be the medium of equalization. If a cloud or ſtratum of air, replete with electricity, ſhould be near the earth's ſurface, diſplacing the air all around, is equally re-acted on by the air, and conſequently will aſſume a cylindrical form. When ſtriking on the earth, that part can only be burnt which is in contact with the air, and which neceſſarily muſt be the circular line bounding the cylinder.

Water ſpouts.—Dr. Stuart, who has given ſome excellent repreſentation of water ſpouts, ſuppoſed the water drawn up by ſuctions. Dr. Franklin ſuppoſed that a vacuum was induced by concentrated currents of air, and that the water was forced up. From a variety of circumſtances they appear to be electrical columns, when diſperſed, being attended with a flaſh, and diſperſed by conducting ſubſtances. If an electrical column paſſes over water, and entirely diſplaces the air, water is a conductor, and conſequently no reſiſtance to that fluid; hence the outer air will force the water up to thirty feet, or till the column of water

becomes

becomes a counterpoife to its preffure. Water fpouts, in general, are about the fize of the maft of a large fhip; when they fall upon a folid body, as a fhip, a maft or part of the rigging will in general be feparated, there being the action of 15lb. on every fquare inch; fo that a water fpout, fix feet in diameter, will be equivalent to 5000lb. Dampier tells us that he faw one, fo large in its progreffive motion, went over a fhip becalmed on the coaft of Guinea, firft threw her down on one fide, and carried away her fore maft, and in an inftant paffed to the other, and carried away her mizen maft.

When thefe electrical columns fall on land, they produce the phenomena of whirlwinds, which tear up trees, remove hay ftacks, &c.

When thefe columns fall on the fcorched fands of Arabia, they are elevated, moving along with the wind, conftituting what are called the *moving pillars of the defart*. In thefe heated countries the air is fo dry, almoft a perfect conductor, and infulated from the earth by the parched fand. Large extent of electric matter moves almoft in a pure, uncombined ftate, appearing like a blufh in the Heavens, rapidly moving; producing all the effects of an abftraction of air, by fuffocating every animal expofed to its influence: and even its effects are felt acrofs the Mediterranean, as far as the fhores of Italy, forming the Siroco of Volney, or the Simoom of Bauce.

Of the different States of Electricity in the ſame Conductor, when brought within the Influence of an inſulated Conductor, which has more or leſs than its natural Quantity of Electricity.

Suppoſing A B, C D, Fig. 4, two braſs or other metallic cylinders, placed in a right line with each other and inſulated, if the conductor A B ſhould be poſitive, or have more than its natural quantity, and brought within an inch or two of the inſulated conductor C D, the end C will be negative, and D poſitive.

Upon a firſt view it appears difficult to conceive how there could be different degrees of electricity in a conducting body, where there is ſuch freedom for equalization.

If A B has more than its natural quantity, ſuch exceſs will form an electrical atmoſphere, as before deſcribed, round the cylinder A B. The exceſs cannot paſs to C D, becauſe of the reſiſtance of the intervening particles of air. The air being acted on, as before mentioned, by the electricity being thus accumulated on the ſurface of the conductor, the particles of electricity ly-

ing

ing about the ſurface of the end of the conductor C a b, meets with leſs reſiſtance in paſſing into conductor C D; but the end D c d will be out of the influence of the conductor A B; having thus an accumulated quantity of electricity, will endeavour to equalize itſelf. In this caſe it will have to overcome the reſiſtance of the air D c d; on this account there will be an increaſed quantity in the end D c d; but the electricity round the ſurface C a b preſſing into the conductor, and forcing the natural quantity to the end D, will have a deficiency of electricity; thus C will be negative, and D poſitive. The deficiency in the end C cannot be ſupplied from the conductor A B, becauſe of the intervening plate of air; ſo that a poſitive conductor, thus ſituated with reſpect to another, does not immediately diſturb the natural quantity of electricity exiſting in the other conductor, but by acting on the intervening air, the electric particles diffuſed in the air not meeting with any reſiſtance in the conducting medium, paſs into this, and force forwards the natural quantity.

If A B be brought ſo near to C D as to entirely overcome the reſiſtance of the air, then C D would not poſſeſs unequal portions.

This may be illuſtrated by the following analogical experiment: the end of a poker being made red hot, when removed from the fire I placed the thermometer on the other end, and aſcertained

tained its temperature to be 58°. I held the thermometer there while I immerſed the heated end in a veſſel of cold water; the thermometer at the cool end roſe ten degrees: thus we find that the contraction which takes place on the ſurface of the heated end, forced the caloric to the other end, and thus increaſed its temperature; ſo that in this caſe the caloric is accumulated at one end by the abſtraction of it from the other end: thus the air round the ſurface being rendered negative, and will give negative ſigns to any conductor brought within its influence.

Let us ſuppoſe one hundred particles of electricity naturally round the ſurface C a b; as the preſſure of fluids is always equal in every direction, there is leſs reſiſtance in theſe particles of electricity entering into the ſubſtance of the conductor C D, than to re-act on the air. As C a b is already in poſſeſſion of its natural quantity, it can receive no farther addition, unleſs by removal of its natural quantity; this will be drove towards the end D c d, as there is leſs reſiſtance in this direction than in any other; for the air round the end C a b, by being thus compreſſed, will reſiſt more than the air round the end D c d; ſo that the power with which the ſurrounding medium acts on the end C a b, will be exactly equal to the reſiſtance attending the impulſion of the natural quantity of electricity forwards, added to the reſiſtance of the ſurrounding air about D c d.

G These

Theſe hundred particles contiguous to the ſurface C a b, are no ways equal to the accumulated quantity round the conductor B; but no more electrical particles can be forced into the end C, but what are contiguous to it; and the conductor C D not being pervious to the air, the compreſſion of the air will only be diminiſhed by the number of electrical particles thus abſtracted. In this ſtate, any body poſſeſſing its natural quantity of electricity will impart a quantity till brought into a ſtate of equalization with the ſurrounding air: thus the ſuſpended pith balls will, to equalize themſelves with the part where they are ſuſpended, loſe a portion of their natural quantity; in this ſtate the balls will not be in balance with the air which ſurrounds them; hence will diverge, as before explained.

For the natural electricity of the body will be under the ſame impulſe from the ſurrounding air as the conductor; thus feathers, pith balls, &c. will diverge by negative electricity when applied to C, and by poſitive electricity when applied to D; and theſe portions cannot equalize themſelves with reſpect to electricity, although in one and the ſame conducting ſubſtance, ſo long as the impulſe at C ſhall be equal to the reſiſtance to its egreſs at D, added to the quantity of electricity; in fact, the momenta are equal. If there is one particle of electricity in the end C drove forwards by a power equal to ten, it will counterbalance

lance two particles at D, which could juſt overcome the reſiſtance of five.

If a non-conducting ſubſtance, as a plate of glaſs, was applied between B and C, there would be no impulſe communicated to the air contiguous to C, becauſe the impulſe from B could not overcome the reſiſtance of the glaſs; and in this caſe the conductor C D would remain undiſturbed.

The Application of theſe Principles to the Explanation of the Leyden Phial.

Let M S be a Leyden Phial, Fig. 5, inſulated on a ſtand Q; let it be coated to a, b, on each ſide, and let N M expreſs the ſingle column of air and electricity, as it naturally exiſts on the inſide, and M O a ſimilar column on the outſide. Suppoſing the proportion as before aſſumed, viz. between two particles of electricity four particles of air, and let O R be a wire, or any other conducting ſubſtance, which may be applied occaſionally to the outſide coating b O, and let P be the conducting ſubſtance, connected with the prime conductor of an electric machine.

In this ſituation it muſt appear evident that the column M N is an exact counterpoiſe to the column M O; if an additional particle of electricity ſhould be thrown into the column M N, ſuch cannot take place without producing the effects as before deſcribed.

Let 1, 2, 3, Fig. 6, expreſs three columns, ſo ſituated as to be prevented extending their lengths, by reſiſting bodies m n, o p. In the column 2 there is an additional particle of electricity; ſuch could not be forced in without compreſſing the particles of electricity and air in that column; therefore, in order to force in a particle of electricity, I muſt make uſe of a power equal to the reſiſtance. If in the third column, I ſhould force a greater number of electrical particles; by ſtill farther compreſſing the ſuperior particles of air and electricity, I ſhall have to overcome greater reſiſtance, and muſt exert power accordingly.

If, for every additional particle of electricity in the column M N, Fig. 5, a particle of electricity is abſtracted from the outſide, they will then be in a ſtate of equality. If, then, a conducting ſubſtance, as O R, be applied to the external coating, there would be leſs reſiſtance in paſſing through here than by compreſſing the air.

Inſtead of the columns of particles of air and electricity being in their original proportion, viz. between every particle of electricity four particles of air, if ſuch a quantity ſhould be accumulated

lated in the column M N, as to be equal in number to the particles of air, then the reſiſtance to the air would be four times greater, acting on the column M b O with this additional force; ſo that whilſt the column M N acquires an increaſed power by the addition of electricity, the column M O acquires an increaſed power of reſiſtance by the abſtraction of electric particles. On this account, in the column M O, the particles of air are in a ſtate of greater approximation than the particles of air in the column M N; that this is the caſe is evidenced to the ſenſes, by the experiment afore mentioned of the aërial pellicle withinſide an egg*.

If the particles of electricity in the column M O do not communicate with ſome conductor, there can be no accumulation in the column M N.

In this caſe there is no medium through which can be forced any of the particles but the electrical; by a powerful compreſſing force caloric may be diſengaged from the air; this muſt be by a force greatly ſuperior to the accumulation of electricity; the particles of air cannot permeate ſolid bodies. If there ſhould be a free and eaſy paſſage for the electricity, then the abſtraction

* The condenſation of the air from the diſcharge of cannon or blowing up of powder magazines have been known to electrify windows.

from

from the one portion will allow of the addition to another.

If the Leyden jar ſhould be inſulated, ſo that the wire R O be removed, the glaſs pillar Q will not allow of any paſſage; by being a non-conductor, contains little or no electricity in itſelf, and conſequently cannot admit of any impulſe; hence the neareſt courſe will be O G, making it a column M O; but the addition of a ſingle particle of electricity added to M N, cannot overcome the longer column M G; and this muſt be overcome to admit of any increaſe in the column M N; as this cannot be done, there can be no accumulation within.

On the metallic Coating.

In the early ſtate of electricity jars were filled with water, and immerſed in the ſame fluid to a correſponding height; when the ſuperior advantages of the outſide having a metallic coating was ſhewn by Dr. Bevis, Dr. Watſon then lined the inſide with tin foil.

Atmoſpheric air, we have already obſerved, is a very imperfect conductor, and no electricity can be accumulated in this fluid, but in thoſe parts

parts that were in contact with conductors; thus to charge a jar uncoated within, the conducting wire must be moved round to every part; by having the wire connected with a metallic coating, the accumulated electricity is immediately diffused, so as to be of an equal intensity; there being no resistance to the equalization, one part cannot be in a state of excess with respect to another, the metallic coating having more than its natural quantity, is more than a balance to the surrounding air, and consequently imparts so much to the aërial portion contiguous to it, till its own excess and the resistance of the air becomes equal. The quantity of electricity imparted in the first instant by being thus diffused, is not of an equal intensity with the wire connected with the prime conductor; a second portion is communicated and diffused, and thus the process goes on till the coated surface, the stratum of air, the wire, and the prime conductor, are in perfect balance; then the jar will not admit of any farther charge.

So the outside coating, if removed, in vain could we charge the jar, unless over every portion of the corresponding part to the inside coating we had a conducting body; this could no ways be so effectually done as by a coating all around: the impulse upon the column M O, Fig. 5, will cause the electrical particles at b to act equally all around; there being less resistance in the

the metallic coating, a particle of electricity is impelled from thence; the loss of any portion of electricity from any one part, the deficiency becomes general; in this state possesses less electricity than to balance the surrounding air; so that all the electricity in the air, in contact with the coating, becomes gradually unloaded; so that the state of the external part is precisely the reverse to the internal coating, both with respect to the coatings and the air.

Metallic coatings have hitherto been considered as only connecting media; they not only answer this important purpose, but likewise considerably increase the quantity accumulated; according to their conducting powers, they possess more or less electricity, hence will admit of a larger quantity to equalize them with the surrounding media. This is the reason why the discharge varies according to the nature of the conducting medium; a jar filled with water will not admit of the same charge as when coated with tin foil; the more perfect conductor the coating substance is, the higher the discharge: red copper is the best conductor yet known; if jars were lined with it, the charge would be greater than with tin foil.

Dr. Franklin was induced to believe that the coating answered no other purpose than a connecting medium; when he had charged a coated bottle of water, by pouring out the water he found the bottle was equally discharged. If we have

have a moveable metallic lining, and after charging remove the lining, and after being unloaded replace it, the discharge we do not find exactly equal to what it was before the disturbance.

From this it is by no means to be inferred that the coating is only a connecting medium. When the bottle is charged, let us suppose the coating, air on the surface, &c. have three times more electricity than natural; in this state they keep each other in balance. When the coating is drawn to the upper part of the jar, it is then in contact with air not so highly charged, and imparts its own excess; by these means the balance withinside the jar and without is preserved, for the coating evinces very little signs of electricity when removed from the jar. In replacing the coating, in passing through the air in the upper part of the jar, it gradually recovers what it had lost, being then in a comparative diminished state, and thus the charge is nearly the same.

Of the Situation of the reſpective Coatings.

Although the utility of metallic coatings on each ſide may be acknowledged, yet the neceſſity of their being exactly correſponding and exactly oppoſing each other, in order to produce the greateſt charge, may not at firſt view appear ſo obvious.

Let A B, Fig. 7, repreſent a ſection of a Leyden pane of glaſs; if a b be the coated ſurface on one part or ſide, then d c ought to be the coated ſurface on the other, in order to produce the greateſt effect.

Let us ſuppoſe one ſide coated d c, and the ſame extent of ſurface b e on the other ſide, but not oppoſed to it; if b e is the charged ſurface, and the electric columns acting all around, but the column b A is greater than the column A d, the loſs ſuſtained by this will be the quantity of electric fluid equivalent to the reſiſtance of the column a b, being the difference between the two columns b A and A d; but e B is leſs than B c; in order to overcome the greater column B c, it will require an additional power equal to b e, the difference between B c and B e; ſo that a pane thus coated will require an accumulation

mulation of electricity on the coated surface equivalent to the abstraction from the surface c d, and to overcome the resistance a b, b e; so that if the difference be so much, as in this case, the plate cannot be charged, it must appear evident, that when the column and spaces on each side the coated surfaces are equal, there is less resistance to overcome; and these spaces can only be equal when the coatings are directly opposite to each other.

When a jar is charged, such cannot be discharged without the same quantity of electricity being restored to its negative side; if this be insulated, we cannot by any means abstract the accumulated portion of electricity on the charged side; the state of the air on the one side is an exact counterpoise to the accumulated electricity on the other. If the accumulated electricity is removed, the air must recover its original situation; and this cannot be done but by means of the restoration of the electric particles; in the insulated state this is impracticable, and therefore the jar cannot be discharged. If a communication is formed between the inside and outside of the jar, the part of the conductor communicating with the inside will abstract a quantity of electricity, in order to be of equal intensity; this will be diffused through the communicating rod, and immediately transmitted to the negative side; so that the instant a portion is given to the dis-

charging rod at the one end, it is forced out at the other; ſo that although we may ſuppoſe it tranſmitted in different portions, as the velocity is ſo great, that the whole appears to be tranſmitted at once, the particles of air being in a ſtate of expanſion on the inſide, and of condenſation on the outſide, the rapid reſtoration produces the report *.

When a jar is about half an inch or three quarters thick, it is incapable of being charged. Let A B, Fig. 8, be the column of electricity and air on each ſide a glaſs of this thickneſs; the column A muſt act in the direction C D B; at C not only acts in the direction D, alſo e; at D

* After the firſt diſcharge there generally remains a quantity of electricity ſufficient for a ſmall diſcharge; this is called the reſiduum, where the jar ſpontaneouſly diſcharges, the reſiduum is very ſmall to when equalized with a diſcharging rod.

The accumulated electricity in contact with the metallic coatings, in conſequence of this chain of connection, is diſcharged at once; this is not the caſe with the portions of air lying on the uncoated ſurface. When the coatings have equalized themſelves, they are then in a different ſtate to the ſtate of air above them; the inſide coating will abſtract a portion of electricity, and the outſide coating will give out ſome of its acquired electricity: this will render a ſmaller charge. Theſe ſmall charges accumulated in a battery will produce conſiderable effect. The reſiduum alone of the Haarlem apparatus, made by Mr. Cuthbertſon, melted two feet of wire.

V. Deſcription d'une très grande Machine Electrique placé dans le Muſeum de Teyler, a Haarlem, par Martinus van Marum.

acts

acts in the direction f as well as B; and B D C being a column much longer than C A, from these united circumstances they prevent any accumulation in the column A, because the first additional portion of electricity is not sufficient to overcome the resistance of B D C. This, as in every other case, demonstrates the necessity of an equality subsisting between these columns, in order to admit of a proper charge.

A Leyden Phial will admit of different Charges, according to the Powers of the Machine.

To the young electrician it appears surprising why a jar cannot be as powerfully charged by a small machine as it can by a larger one; the only difference would appear, that it would compensate in time what it wanted in power. I have already shewn that a small plate or cylinder will not accumulate so much electricity as a larger one, although so arranged as to have the same surfaces rubbed in the same time; when a larger machine has its proportioned-sized rubber, the quantity produced will be proportionably greater. If in the Leyden phial we suppose a machine so small

ſmall as to throw in every excitement a ſingle particle of electricity, there would only then be formed a ſingle column. If the machine ſhould be ſo large as every excitement to pour in four particles of electricity, in this caſe the charge will be made as ſoon again, and twice the ſtrength; as acting equally every way two columns will be formed, and ſo on in the ratio of the powers of the machine: thus, by one of Mr. Cuthbertſon's two-feet plate-machines, a coated ſurface of one foot will admit of ſuch a charge as to melt two or three inches of wire, which in vain could be attempted by a cylinder of equal ſurface.

Spontaneous Diſcharge.

When the air is very dry, from the greater reſiſtance to the electric fluid, fewer columns are formed; thoſe which are formed are formed more rapidly, ſo that the accumulated electricity M N, Fig. 5, in the inſide of the glaſs, extending upwards above M, the reſiſtance between the equalization of the oppoſite column being diminiſhed, this is overcome, and the phial is ſpontaneouſly diſcharged. If we diminiſh this non-conducting power

power of the air, by breathing into the jar, the electricity meeting with lefs refiftance, by the diffufion of this conducting fubftance, the accumulated particles of electricity may proceed, not only upwards, but alfo laterally in the direction 1, 2, 3, 4, Fig. 5; fo that a greater number of columns will be formed, a greater quantity of electricity accumulated, without any fpontaneous difcharge.

That the accumulated electricity acts equally every way is evident from its breaking through the fides of the glafs, if made thin, either by a fpontaneous difcharge, or by determining the whole accumulation to one particular part by the difcharging rod.

Explication of fome Electrical Phenomena.

Mr. Atwood had obferved, that if there were an interrupted circuit of wires, about twelve feet, connected at one end with the infide of a jar, and the other end with the outfide, that in charging the jar fparks of electricity appeared, as if proceeding from each end of the wire, and extending gradually to equal diftances, till they approached each other, and were then difcharged.

Mr.

Mr. A. ſuppoſes this a demonſtration of there being two electricities, active when in a ſtate of ſeparation, and paſſive when united. This appearance is eaſily explicable on the preceding principles; in charging the jar, every additional particle thrown into the jar will force out a particle from the outſide; the inſide of the jar, in equalizing itſelf with the conducting wire, will impart ſo much as to equalize itſelf. This firſt accumulation, on account of the diviſion of the conductor, may extend ſix inches; after ſuch a diffuſion, it becomes too weak to ſtrike through the little intervening portions of air; after a ſecond excitement of the machine, it may be tranſmitted twelve inches, and ſo on, till it has arrived at ſix feet. As exactly the ſame quantity of electricity is thrown off from the outſide, the ſame appearances muſt take place, paſſing through equal ſpaces in preciſely the ſame time; ſo that each proceed ſix feet, the communication is formed, and the charge is unloaded.

When electric ſparks are paſſed through a partially-exhauſted tube, the faintneſs in the middle has been ſuppoſed to be owing to the union of the two electricities; this faintneſs is regulated by the form of the inſtrument. If a perfect cylindrical one, as is ſometimes uſed for the Guinea and Feather, and two even plates of braſs, applied one at bottom, and the other at the top, the electricity is then univerſally diffuſed, and no particular

cular faintneſs in any part. If, as uſually made, with a ball at one end, and a point at the other, the whole is explicable on the common principle of elaſtic fluids, the electricity proceeding from the ball in a diverging direction, as it diverges muſt be fainter; the leaſt reſiſting direction it can afterwards move in muſt be in direct lines to the conducting ſubſtances; hence will appear converging, and thus concentrating will be more luminous.

Poſitive and Negative Light.

When a conducting ſubſtance poſſeſſes more than its natural quantity, in giving it out freely to the ſurrounding air will be ramified, and in the form of a bruſh.

If the conducting ſubſtance ſhould be in a ſtate of deficiency, the electricity in the air will not be ſo freely tranſmitted; it will only appear like a little luminous ſpot or ſtar on the conductor.

Theſe different appearances merely depend upon the different freedom with which the exceſs is tranſmitted.

Points.

Mr. Hopkinſon, one of the Pennſylvanian experimentaliſts, expecting that by means of points he could concentrate the electric fluid, and thus have a more powerful ſpark, was ſurpriſed to find little or none. Dr. Franklin, with his uſual liberality, having firſt ſuppoſed that this might depend on the attraction being in proportion to the ſurfaces, confeſſes that this explanation is the beſt he could offer, yet did not think it ſatisfactory.

Volta and other electricians have ſuppoſed points are coatings to an infinitely ſmall plate of air.

Upon the preceding principles, the theory of points admits of an eaſy ſolution.

Any conducting ſubſtance in a poſitive ſtate of electricity will act as a centre to the aërial portions all around, and which will recede in concentric circles; that a conductor, whoſe ſurface is large, will neceſſarily require a power to diſturb or diſplace its own electricity, in proportion to its extent of ſurface. If there ſhould be a thouſand particles of electricity in the expoſed ſurface

surface of a conductor, it would require a proportionate number of particles to disturb them; or if a fewer number, an additional power; if only 100, each particle must be impelled by a power ten times greater than if one thousand. In a point, comparatively speaking, there is but a single particle; and consequently, if the point comes to the verge of the circumference of the sphere formed round the conducting body, it will admit of a single compressed particle; this particle being removed, another succeeds, and thus the point silently steals the fluid away; while a body with a surface must enter into that sphere, till it arrives at that part where the electricity of the air can overcome the resistance of the fluid in the conductor.

ESSAY

ON

MEDICAL ELECTRICITY.

I HAVE already observed, that all fluids yet known, except air and oil, contain more or less electricity, and will freely allow its ingress, as well as egress. As the human body is principally constituted of fluids, it is replete with electricity, and sensible to the least disturbance. A person insulated, giving a spark of electricity, is not identically the same portion he received from the machine, but an equal quantity forced out of his body by the impulse of that he received from the conductor. When thus connected with an electrical machine, a man, become a part of the conductor, participates of the intensity, and equalizes with the whole.

Upon

Upon this confideration, the human body we muft regard as a fubftance through which, in every part, electricity is diffufed; fuch being the cafe, there can be no farther addition but what an adequate portion will either be tranfmitted to fome conductor, or form an electrical atmofphere round the body, as before defcribed.

Obedient to the fame general laws by which fluids are governed, the electric matter, upon any impulfe, moves in that direction where it meets with the leaft refiftance; and, as being an elaftic fluid, the force of the impulfe will be in the inverfe cubic ratio of the diftance of any part from the line of direction.

If a perfon takes a very gentle fhock, he only experiences an uneafy fenfation at the tip of his fingers; if the fhock is a little ftronger, he feels it about his arms; if ftronger, it agitates his body.

It is very eafy to comprehend why we fhould experience the electrical fenfation at the extremities when connected with the Leyden phial; the quantity of electricity entering the body has in that part to overcome the refiftance of the electricity inherent in the fingers; from the fingers the impulfe is tranfmitted through the body; the fingers which are in connection with the negative fide of the bottle in paffing out, has to overcome the refiftance of the egrefs, and thus the fenfation is induced.

If

If the impulſe is more violent, the effects of the impulſe will be more extended.

In the human body we can either increaſe or diminiſh the natural quantity of electricity, or diſturb the relative ſituation of the whole.

Abbé Nollet obſerving that fluids in capillary tubes flowed quicker when electrified, on this account he ſurmiſed, that by ſuch means the circulation of the fluids might be much increaſed: he tells us that he found animals diminiſh in weight by electricity, and that a young man loſt, in five hours electrifying, ſeveral ounces more than his uſual quantity.

Kratzenſtein, Profeſſor of Halle, ſays, by means of electricity he raiſed a man's pulſe from 80 to 88.

Sauvages, the celebrated noſologiſt, aſſures us that the pulſe is increaſed about one-ſixth. Monſ. Gerhard ſays, that in irritable people it is increaſed double (V. Mem. Berlin. Acad.). Cavallo mentions that both the negative and poſitive increaſe the pulſe about one-ſixteenth. In order to aſcertain whether electricity would increaſe the pulſe, it was accurately tried by the following gentlemen, viz. Dr. Deiman, Van Marum, Van Trooſtwyk, and Cuthbertſon, with the powerful apparatus at Haarlem; the pulſe of no one was in the leaſt influenced either by negative or poſitive electricity. I have frequently tried myſelf, as well as others, when in health or indiſpoſed, yet have

have never obſerved any increaſe in the circulation.

The effect of electricity is, by diſturbing the natural quantity inherent in any part of the human frame, and by thus altering the action of that part, inducing certain changes.

That ſuch changes may be conducive to health, it becomes requiſite for the adminiſtrator of medical electricity, to well aſcertain the ſeat of the complaint, to know the different ſenſibilities of the different parts, and the effect of electricity upon them.

There are many complaints which would be conſiderably aggravated by the imprudent uſe of electricity, and a great number of other affections, which could no ways be benefited by this important agent, unleſs carefully applied.

To apply electricity to the region of the diaphragm in the ſame manner we would to a rheumatic affection of the extremities, what proſtration of ſtrength would be the conſequence; that exquiſitely ſenſible ſeptum by ſuch an action would be deranged in its functions, and reſpiration for a time impeded. It would not be again reſtored till the lungs were diſtended by a ſighing inſpiration, and the diſturbance ſoothed in a flood of tears.

So in paralytic affections in any derangement of the nervous ſyſtem; to produce any good effect, the impulſe muſt be made on the ſource of the

the complaint; in the palsied extremity to apply electricity to the foot alone, no advantage could ever arise; we ought in this, as in every other case, to attend to the source of the disease before we can afford the wished-for relief.

Medicines are principally confined in their actions on the stomach, and some few can be communicated to the lungs; to all other interior parts we possess no power of determining any particular medicine, unless electricity be regarded as such: this principle we can direct in what manner we please. The muscles, ligaments, or even solid bones, are, as it were, capacious vessels, affording easy transmission to this fluid; and, as we can regulate the power at pleasure, we are thus in possession of an active, penetrating principle, by which we can produce a variety of actions in different parts.

It is a law in the animal economy, that two different actions cannot exist in any one part of the human frame at one and the same time; when the natural action is any ways altered, it will be removed by inducing another that will counteract it. We ought to be extremely careful that the action we induce be exactly proportionate to the nature of the derangement. If a part affected should be in a state of great irritability, or labouring under any violent inflammatory affection, the complaints would be aggravated by the disturbance of electricity. All those cases which

appear

ERRATA.

Title page, *of* the Author, *read* *by* the Author.
Pref. p. 5, Note, *l.* 4, *Lieber Kuhn, read Lieberkuhn.*
Page 6, *l.* 20, *Beocaaia, read Beccaria.*
—— 3, Electricity *in* a fluid, *read* *is* a fluid.
——12, *l.* 18, *elasticity, read electricity.*
——16, *l.* 16, *equalize, read equalizes.*
——37, Note, *l.* 7, *depends, read depend.*
—— *l.* 12, *ensues, read ensue.*
——38, *last l. Bauce, read Bruce.*
——68, Note, *l.* 6, *this* fibrillæ, *read these* fibrillæ.
——71, Note, *l.* 4, *cenuminous, read ceruminous.*

appear to be connected with diminiſhed powers of life, as in dull, deep-ſeated obtuſe pains, or any interruption to the functions of the nervous ſyſtem, or by the increaſe of any ſecretion, in theſe electricity is highly beneficial.

FINIS.

AN

AN ANALYSIS OF A *COURSE of LECTURES* ON THE PRINCIPLES OF NATURAL PHILOSOPHY,

By C. H. WILKINSON, Surgeon,

OF THE

SOCIETY OF ARTS,

MEMBER OF THE PHILOSOPHICAL SOCIETY

OF

MANCHESTER,

AND

LECTURER ON EXPERIMENTAL PHILOSOPHY

AT

St. BARTHOLOMEW's HOSPITAL.

London:

PRINTED FOR M. ALLEN, 15, PATERNOSTER-ROW.

1799.

AN

ANALYSIS

ON THE

PRINCIPLES

OF

NATURAL PHILOSOPHY.

MATTER.

MATTER, as derived from *Mater*, the mother, in the abſtract implies a more confuſed and general idea of ſolidity, with little or no regard to figure, proportion, or quantity; the form under which Matter appears, is generally termed *body*, and that which ſupports or ſtands under the different forms which are preſented to our ſenſes, is characteriſed by the word *ſubſtance*.

Matter exiſts wherever there is a RESISTANCE. Figure and extenſion are ſuperfluous in the definition.

Matter in its primary ſtate is homogeneal, by the different combinations of theſe primary particles produce a proportionate variety in the conſtituent particles, which by their arrangement form the different claſſes of natural bodies that compoſe this earth.

Thus it may be ſuppoſed that two primary particles united, may form a conſtituent particle of light; three particles united, a conſtituent particle of fire; four, a conſtituent particle of air: and thus by different combinations, form that great variety of bodies we ſee.

To theſe conſtituent particles our chemical powers are limited; a conſtituent particle of mercury can no ways be changed into a conſtituent particle of gold. The powers of life can reduce theſe conſtituent particles, and by different combinations produce different reſults.

Had the globe been placed in any other part of the univerſe, the nature of bodies muſt have been materially different. Under the influence of different cauſes, different combinations would have taken place: the principle of life diffuſed through the univerſe being rouſed to different actions, the combinatory products would have differed alſo.

The different ſtates in which Matter appears are three:

First.

First. A ſtate of fortuitous concourſe, where in its accumulation no ſpecific form has been aſſumed, no peculiarity of appearance defined.

Secondly. The arrangement by the power of life, to which the greateſt portion of natural bodies is reducible, as *wood*, *coral*, *ſhells* of all cruſtaceous animals, *marble*, *ſtones*, *ivory*, *metals*, *coal*, *ſulphur*, and probably every ſubſtance which has an uniformity in its appearance, without any cryſtaliſing arrangement, to this cauſe may be attributed.

By this power the female glow-worm forms her phoſphorus, the bee its honey, and the ſerpent its poiſon.

Thus fern leaves conſiſt of one quarter iron: this metal is not found peculiarly in the earth in which the fern vegetates, nor in the air which ſurrounds the plant. It muſt originate from ſome powers of combination inherent in the plant; the ſame powers which form the peculiar ſap, the ſame can convert the conſtituent particles of one body into thoſe of iron.

Thus ſhell-fiſh can convert their own nouriſhment into envelopements of aërated lime, and the coral formed into maſſes of an enormous extent by the united labours of myriads of polypes: from theſe all ſpecies of calcareous earth derive their origin, as marble, ſtones, &c. In the Atlantic

Ocean and the Northern Seas are extenſive rocks of coral daily increaſing; theſe in the courſe of ages lay foundations to iſlands: we may thus conceive how Delos and Rhodes roſe out of the ſea, and the two iſlands of the Azores which emerged in the ſixteenth century.

As theſe combinations are the reſult of the agency of life, according as this principle is influenced, ſo the products will be alſo. Thus the debilitated ſtomach of the gouty patient, inſtead of performing its duty with its uſual energy, decompoſes the fluid with which it is ſupplied, and converts it into large quantities of air.

Thus animal ſubſtances under certain circumſtances, with reſpect to temperature, moiſture, and air; the balance of affinities is ſoon broke, and the putrefactive proceſs takes place.

When the ſame ſubſtances are placed in water, the ſame changes do not take place, the principle which in the one is evolved, is here retained, and the whole converted into a waxy ſubſtance.*

So

* My friend Dr. Gibbes of Bath, well known for his accurate experiments on the converſion of the component parts of animal ſubſtances, into a kind of ſpermaceti, thus elegantly explains the change which fleſh undergoes in water.

" Fleſh

So vegetables, when preſſed by large maſſes of earth from the unequal action of earthquakes, or the overwhelming of volcanic powers; where whole foreſts are ſwept down and ingulphed by thoſe convulſions; the amazing ſuperincumbent preſſure, and the different change of ſituation, conſolidates and converts the vegetable ſubſtance into coal; and thus under a little change of circumſtances, may be converted into ſprings of Petroleum and rivers of Naptha.*

" Fleſh and animal matters in general, are compoſed of
" oxygene, hydrogene, carbone and azote; water is com-
" poſed of oxygene and hydrogene, and the ſubſtances which
" are formed are fatty matter, or a triple combination of
" oxygene, hydrogene, and carbone; ammonia, in ſmall
" quantities, compoſed of hydrogene and azote; carbonated
" hydrogenous gas compoſed of hydrogene and carbone;
" and nitrous acid compoſed of oxygene and azote.

* Coal mines in the vicinity of volcanoes, there are ſprings of Petroleum and rivers of Naptha. At Baku there are ſtreams of Naptha in a continual ſtate of combuſtion.

Thus the vegetable fixed alkali is formed from the Lixivium of common wood aſhes, while the mineral alkali is obtained by the ſame proceſs from marine plants: ſituated on the Weſt of Delta, Sicard and Volney tell us of lakes of Natron found in a native ſtate.

Thus in the former caſe the vegetable forms an union of nitrogenous gas with lime to conſtitute pot aſh; while in the latter the gas unites with magneſia to form the ſoda.

So ſulphur is formed by the decompoſition of vegetables and animals; and Monſieur Deyeux ſays it exiſts naturally in certain plants.

Third State of Matter is the arrangement by cryſtallization. In various minerals we obſerve a ſomething more than a mere fortuitous concourſe of the conſtituent particles; there is a ſymmetric aſſemblage, a beautiful arrangement, appropriate to particular bodies. When theſe preſent themſelves under any regular form, whoſe faces may be repreſented by geometrical figures, ſuch are called cryſtals.

This arrangement can only take place when the conſtituent particles are in a fluid ſtate, and running gradually into a ſolid form.*

It has been thought that this arrangement is effected by the influence of a power, a degree inferior to vegetable life.†

Since

* If we dip a thread into a ſolution of allum, we find the thread will be covered with little cryſtals of an octohedral form; if we again immerſe the thread, we do not find an accidental ſcattering of the ſame cryſtals in different parts of the thread. The ſucceſſive layers are determined to the firſt cryſtals, increaſing their ſize with the ſame octohedral form.

† Haller obſerves that animal life is a degree above vegetables, and vegetable life a degree above cryſtallization. Von Linnæus ſays, " Lapides creſcunt, vegetabilia creſcunt & vivunt;

Since Mr. Lichtenberg has ſhewn what beautiful configurations may be produced on an electrephorous, and the ramifications influenced by the ſtate of Electricity, with ſome degree of reaſon it has been thought that cryſtallization may be owing to the influence of the ſame principle.

As bodies have different capacities for Electricity, ſo the conſtituent particles of different minerals poſſeſs different degrees of power; if they are influenced in their arrangement by this power, each animal muſt have its own reſpective arrangement.

When the proceſs is ſlow, the arrangement is ſymmetrical and regular; when hurried, the ſurfaces are ill-formed, and ſometimes an aſſemblage of almoſt imperceptible moleculæ.*

vivunt; animalia creſcunt, vivunt & ſentiunt." Monſieur Metherie and others have ſuppoſed that there are ſeeds of cryſtallization, that there is a ſpontaneous generation in the mineral kingdom; they have extended this doctrine ſo far as to ſuppoſe animals or vegetables are produced by the cryſtallization of the ſeed.

* Such is the difference between a rhomboidal calcareous ſpar, and a block of ſtalactites, or white marble; between a regular cryſtal of ſelenite, and the common gypſum or alabaſter; between a quartz or rock cryſtal, the hexagonal ſpecies with iſoſceles triangular planes, and the unformed quartz, as freeſtone, agate or flint.

When

When rendered fluid by heat, they are ſubject to the ſame influencing principle, and arrange themſelves in perfect order; inſtead of acting from a centre, they terminate here, and commence from the circumference.

This is the reaſon why the conſtituent particles of bodies rendered fluid by heat are more firmly united, than the arrangement of thoſe held in watery ſolutions.

In the cryſtallization of ſalts, each particle acts uncontrouled by any ſurrounding medium; not ſo with melted glaſs or metals; the ſurface is firſt cooled, and which neceſſarily prevents the expanſion of the interior portion, ſo that the conſtituent particles are gradually more and more wedged with each other.

Glaſs, when gradually cooled, is regular in its arrangement, if ſuddenly cooled or unannealed, break, however thick, with the ſlighteſt tremor.

Exp. with glaſs proofs.

Exp. Batavian, or Prince Rupert's Drops.*

ON

* Theſe Drops are known in England by the name of Hand-Crackers, of a pear-like form, with a long tail; when a ſmall part of the tail is broke off, the whole Drop is reduced into powder.

They are made by letting drops of melted glaſs fall into a veſſel of cold water; the tails are afterwards drawn out by means of a lamp.

The

On ATTRACTION and REPULSION.

All the experiments which have been advanced in order to demonſtrate the exiſtence of certain active powers, may be reduced to the five following.

1. The tendency of light bodies floating on the ſurface of water contained in a veſſel, towards the ſide of the veſſel.

The glaſs is very rapidly cooled, and, as before obſerved, the conſtituent particles in a very imperfect ſtate of union: the interior portions of the Drop are ſlower in their cooling as they approach the centre, ſo that every ſucceſſive portion will have their conſtituent particles in a more perfect ſtate of union, and conſequently in a ſtate of greater approximation; as ſuch, every interior portion will recede from the exterior, forming involucra like the concentric partitions of an onion. All theſe ſpaces muſt be in the moſt perfect ſtate of exhauſtion, free from every particle of air.

That theſe intervals are in a ſtate of exhauſtion, may be farther proved, by rendering the Drops ſoft by heat; the bubbles diminiſh, from the glaſs, being compreſſed by the external air.

When a portion of the tail is broke off, a communication is formed between the atmoſphere and theſe concentric vacua; the air ruſhes in with violence into all the exhauſted intervals; each vitreous involucrum yielding to the tremulous impulſe, the conſtituent particles ſeparate, and the whole falls into ruins.

2. The

2. The riſe of fluids in capillary tubes.

3. The force with which two poliſhed leaden ſpheres cohere.

4. Reflection and inflexion of light.

5. Expanſion of bodies by heat, and contraction by cold.

Theſe are all reducible to pure mechanical principles, principles which are cognizable to every mind.*

The terms *powers*, *ætherial atmoſpheres*, *attractive* and *repulſive influences*, will be totally rejected as principles whoſe exiſtence we are unable to conceive, and which, inſtead of elucidating any phænomena of nature, involve them in ſtill greater obſcurity.

We ſhall hereafter ſee that in Electricity, Magnetiſm and Gravitation, that the adoption of ſuch terms is not only unneceſſary, but alſo unphiloſophical.

* For the more particular examination of theſe experiments, the reader is referred to ſome phyſiological and philoſophical eſſays I lately publiſhed.

LECTURE

LECTURE II.

LAWS OF MOTION.

FROM the ſubjection of Matter to the influence of external agents, is deduced the firſt Law of Motion.

LAW I.

Every body perſeveres in its ſtate of reſt or uniform motion in a right line, until ſome external force acts upon it.*

* The paſſive ſtate of bodies eaſily ſuggeſts to us the idea of its continuing in a ſtate of reſt, unleſs influenced by external powers: when impreſſed, the perpetuity of its motion is not ſo conceivable.

A man ſailing in a boat, or riding on horſeback, if the boat or horſe is ſuddenly ſtopped, he falls forwards.

The ancients had many quibbles about motion; Diodorus Siculus denying its exiſtence, and Zeno endeavouring to prove the ſame from the circumſtance of Achilles and the tortoiſe.

On the contrary, more modern philoſophers, as Wolfins, &c. have thought motion an active principle in matter, and which they have termed vis viva.

The

The reſiſtance Matter makes to Motion, is called its *vis inertiæ*.

To term a *negative quality* a *power* is not ſtrictly philoſophical, as being perfectly ſuperfluous, ought to be rejected as unneceſſarily embarraſſing the ſtudent's mind.

LAW II.

The change of Motion is in proportion to the force impreſſed, and takes place in the direction in which the force acts.

A quieſcent body receiving an impulſe, moves with a velocity in ratio to the power with which it is impelled.

Motion of any whole is the ſum of the motion of all the parts; it becomes doubled in a double body moved with equal velocity, and quadrupled in a double body moved with a double velocity.

Momentum (ſometimes called ſimply motion) is that force with which bodies change their place.

This is always in proportion to the quantity of Matter multiplied by the velocity.

The battering-ram of the ancients being in weight 41,112 pounds, in a ſecond of time was moved one foot. A cannon-ball of 36 pounds moves 1142 feet in a ſecond of time: theſe multiplied produce 41,112, equal in power to the battering-ram.

LAW

LAW III.

Action and reaction are equal and contrary.*

These three laws of Motion are assumed by Sir Isaac Newton as the fundamental principles of mechanics, as such are found to agree with all experiments and observations, are considered as mathematically true.

COMPOSITION AND RESOLUTION OF MOTION OR FORCES.

If a body be acted upon by any two single impulses, it will describe the diagonal of a parallelogram, in the same time it would have described either side, had the forces acted separately.

When a body is kept at rest by three forces, they will be as the three sides of a triangle, parallel

* To illustrate the law of action and reaction. According to Mersennus, a 24 pounder weighing 6400 lb. gives its ball an uniform velocity of 640 feet in a second. The momenta of the cannon, and the cannon and the ball will be equal; hence 24×640 equal to 6400×24, so that on an horizontal plane the cannon would recoil near two feet and a half. Thus conversely by knowing the weight of a cannon and its recoil, the momentum of the ball is ascertained.

to

to the direction in which they act. If ever so many forces acting against one another are kept in equilibrio by these actions, they may be all reduced to two equal and opposite forces.

Two forces acting at the same time on a body, in directions which are oblique to each other, do not move the body by that part of their force, which on account of their obliquity is opposite and contrary, but by what remains after the opposite forces are deducted.*

CENTRIFUGAL POWERS.

Bodies when thrown into motion, their tendency to recede from the centre of motion will be in the ratio of their momenta.

* It was objected to Galilæo, when he asserted the motion of the earth from West to East, a cannon ball shot upright, would not fall down in or near the place where it was shot. A ball fired out of a cannon elevated perpendicularly, and placed in a vessel in full sail, would fall down in the cannon's mouth.

So a ball dropt from the top of a mast of a ship in full sail, would fall directly to the bottom of the mast.

The action communicated to these moving bodies, is the result of two forces, the propelling action, and the action or motion of the vessel, &c.

Illustrated

illuftrated by many experiments on the whirling table.

Thus a bottle of any liquor (which after having been muddy, is by length of time become fine, and is again made foul by fhaking) may fooner be brought to be fine by a centrifugal force, than by being fet upright at reft.

Upon the fame principles the weights of the fame body differ in different latitudes. The earth in its diurnal revolution, the velocity of matter is neceffarily in the ratio of its proximity to the equator; this circumftance influences the vibrations of pendulums ten times more than their expanfion by heat; firft obferved by Richer at Cayenne.

From this obfervation it was that Sir Ifaac Newton demonftrated that the equatorial diameter is about $\frac{1}{120}$ greater than the polar diameter.

Under the equator, bodies are carried round with a velocity of 1040 miles in an hour.

This is farther illuftrated by the appearance of Jupiter, which being a much larger planet than our earth, and its diurnal revolution being performed in lefs time, is neceffarily a more oblate fpheroid, or more refembling an orange.

This was accurately afcertained from telefcopic admeafurement by Mr. Pound, who found that

the equatorial diameter of Jupiter is $\frac{1}{12}$ longer than the polar diameter.

Caſſini depending on ſome inaccurate meaſures of Picard, of the meridian from Paris to the Pyrenean Mountains, endeavoured to prove the earth was an oblong ſpheroid, or like an egg; whoſe polar axis exceeds the equatorial diameter by 34 leagues.

As theſe admeaſurements were made by a 10 foot ſector, where the 200th part of an inch anſwers to 8 ſeconds of a degree, the error of a ſingle ſecond would be equal to 130 fathoms.

To determine this diſpute, Louis XIV. at the requeſt of his miniſter Colbert, ſent Bongouer, Condamine, Don Ulloa to South America, Maupertuis, &c. to Lapland; they aſcertained the meaſures of a degree as follows:

Under the Line	56,753	toiſes
45 deg. lat. -	57,028	
Paris 49 deg. lat.	57,069	
51 & 52 deg. lat.	57,100	
Lapland - -	57,422	

A French toiſe being equal to 6,408 Engliſh feet.

When on any meridian line the altitude of the Pole is obſerved proceeding Northwards till the elevation

elevation is one degree more, or Southward till the height is one degree lefs, the diftance between thefe two places is eafily afcertained by Trigonometry when the *fundamental bafe* is known.

CENTRIPETAL POWER, OR GRAVITATION,

Is the tendency of matter, with refpect to terreftrial beings, to the centre of the earth.

Copernicus regarded it as an *appetentia* that the Creator had impreffed on all kinds of matter. Tycho Brahe, and his pupil Kepler, had fome imperfect theories.

The caufe of gravity is ftill involved in impenetrable darknefs. Dr. Halley refers it to the immediate agency of the Creator. Mr. Cotes deems it effential to matter, like extenfion and mobility. Newton attributes it to fome undifcovered and invifible mechanical affection of matter, and rather fuppofes the exiftence of fome kind of æther, rarer within the denfe bodies of the fun and planets, than in empty fpace.

It is difficult to conceive a fluid fubtle enough to penetrate the inmoft receffes of denfe bodies, and

ſo rare as not to impede their motions, ſhould yet be deemed capable of communicating motion.

Fluids preſs according to the ſurface expoſed, while gravity is always in proportion to the quantity of matter.

To aſcertain whether ſuch a power as gravitation exiſted, Bougouer in 1738, when at Peru, tried the largeſt of the Andes, whoſe bulk to the earth was as 1 to 2000, there was no coincidence.

Dr. Maſkelyne more accurately tried this on the mountain Schehallien, in Perthſhire, and which conſiderably more influenced the vertical poſition of the plumb-line.

May not gravitation be the mechanical effect of the motion of the earth in its orbit? all terreſtrial bodies participating of the ſame impulſe, would hence have a tendency to perſevere in this motion, according to the quantities of matter.

Upon the ſame principle may be explained the different weights of the ſame body in different latitudes.

The earth in its orbit moves at the rate of 1,600,000 miles in a day, while it has a contrary motion round its axis from Weſt to Eaſt.

The portion of earth near to the Line moves about 1040 miles every hour. In the latitude of England, the motion of bodies is not more than

600

600 miles. At the poles of the earth there is no counteracting motion.

From this it would appear that a body weighing 70 pound at the Poles, would weigh a little more than 69 pound and a half in England, and 69 pound under the Line.

So that a body weighing 200 pound in England, would lose near one pound when under the Line.

This circumstance nearly coincides with experience, as Mr. Richer observed at Cayenne, from the transits of the fixed stars over the meridian, that his clock lost two minutes, twenty-eight seconds per day, and hence it was necessary to shorten the pendulum one line and a quarter.

Four or five years after, Dr. Halley observed the same at St. Helena, and remarked that the increase of temperature would only have expanded the pendulum as to have required the 70th part of an inch, while the diminution of gravity obliged him to shorten it the 7th of an inch, or ten times more.

Of the DESCENT of BODIES.

When a body near the ſurface of the earth is left to itſelf, it falls towards the centre of the earth with an accelerated force.

Galilæo firſt explained this, and demonſtrated that this increaſed as the ſquares of the times of deſcent.

Newton aſcertained, by letting a heavy body fall from the dome of St. Paul's, that it paſſed through 16 feet and one inch, in a ſecond of time.

A body at the end of its fall in one ſecond, if continued on with the velocity it acquires in the laſt inſtant of time (ſuppoſing a ſecond divided into a number of inſtants) would deſcribe double ſpace, as the gravitating power ſtill continues, being added to it, will make the deſcent in the ſecond moment 48 feet and a quarter, and nearly 80 feet and a half in the third, &c.

This impulſe acting with gravitation, occaſions the proportionate acceleration in the arithmetical ratio of 1, 3, 5, 7, 9, 11, &c.

A heavy body falling in the firſt moment will be 16 feet and a half, in the ſecond moment three times

times this number of feet, in the third moment five times, &c.

Five times added to three and one make the fum of nine; by multiplying this by 16 feet and a half, will exprefs the fpace it has gone thiough at the end of three feconds; as the fquare root of nine is three, the fpaces gone through will be as the fquares of the times.

The percuffive force of falling bodies may thus be afcertained. One pound weight falling from the height of one foot, acquired a momentum at the end of its fall equal to three pounds, at four feet fix times, fixteen feet twelve times, thirty-fix feet eighteen times.

Thus 500 pound falling from the height of fixteen feet, would acquire a momentum at the end of its fall equal to three ton weight.

As the fame time is nearly expended in the afcent as in the defcent of bodies, by obferving the time elapfed between its being thrown up and its return, may afcertain the height. Thus alfo the depth of a well or pit may be known, by letting a ftone fall.

All bodies whatfoever fall with equal velocity, provided they pafs not through a refifting medium.

CENTRE OF GRAVITY.

In every body there is a certain point, which if ſuſpended, all the reſt are kept in equilibrio; this point is called the Centre of Gravity.

A line drawn from this point towards the centre of the earth, is called the Line of Direction. In this line all bodies will deſcend with equal velocity.

When inclined bodies are ſet upon an horizontal plane, they will fall the way they incline, if the Line of Direction does not fall within the baſe. When it does fall within the baſe, they may be conſiderably inclined, and yet ſupported; as is the caſe of the inclined tower at Bologna.

Exp. 1. Double cone rolls upwards, when the elevation does not exceed the radius of the baſe.

Exp. 2. The truncated cone for raiſing water from great depths, and emptying it in troughs.

Exp. 3. Bucket of water.

Exp. 4. Stick broke on two glaſſes.

Exp. 5. Inclined cylinder.

PEN-

PENDULUM.

Any body hanging from a point is called a Pendulum.

Galilæo, from obſerving the ſwinging of his lamp, firſt remarked, that the vibrations, whether ſlow or quick, were performed in equal times; and hence thought it might be made uſe of as a meaſurer of time.

Huygens was the firſt who applied it to clocks.

A Pendulum 39 inches and two-tenths vibrates once in a ſecond; to vibrate once in two ſeconds, it muſt be 159 inches, or four times as long; ſo that the lengths will be as the ſquares of the times.

As Pendulums are ſubject to changes in the ſame latitudes, from diverſities of temperature, when expanded in ſummer will move ſlower; to remedy this there is a ſcrew placed at the bottom of the Pendulum, called a regulating bob, in order to adjuſt it.

To rectify this, various ſchemes have been adopted; metals expanding in contrary directions, in order to counteract each other, united in the form

form of a gridiron, others made of glaſs filled with mercury.

The length is taken from the ſuſpended point to the centre of oſcillation, the heavier the bottom part of the Pendulum is the more accurate.

MECHANICS.

Every thing is called a power which is capable of acting upon a body, and every power which can thus act upon matter is ſuppoſed to be material, without regarding any abſtruſe ſpeculations reſpecting its nature.

The mechanical powers are generally reduced to ſix: the Lever, Wheel and Axle, the Pulley, the inclined Plane, the Screw and Wedge. To theſe a ſeventh may be added, as one whoſe mechanical advantage is extenſive, and which cannot be reduced to any of theſe, viz. the Spring.

I. The LEVER.—Of theſe there are three ſpecies: firſt, when the preſs lies between the weight and power; as ſciſſars, pincers, ſnuffers, hammer, crow, &c. Second ſpecies, is when the weight is between the fulcrum and the power, as oars, doors, two men carrying a load upon a ſtick, &c. Third ſpecies, is when the power is between the weight and

and the fulcrum, as in rearing a ladder, so all the muscles of the human body. In all these the power is to the weight inversely, as their distances from the fulcrum.

OBLIQUE LEVERS.—-These are adopted when the motions cannot be directly applied in the direction of the motion required, such as wind-mills where the air acts in an oblique direction; so in water-mills, in pumps of all kinds where the crank is applied; in these cases part of the real power must be applied to no efficient purpose, and the remainder only becomes the real motive force.

COMPOUND LEVER.—If the Levers are of equal power, whatever number there are combined, the united powers will be as the power of one Lever, whose index is the number of Levers.

This is said to be the construction of a machine of Archimedes: on this principle depends the weighing machines.

Second Mechanical Power, the WHEEL and AXLE. In this the power is to the weight, as the diameter of the Axle is to the diameter of the Wheel. If there are several Wheels so constructed that the circumference of one acts upon the Axis of the other, the power is to the weight as the sum of the diameters of the Axles is to the sum of the diameters of all the Wheels.

Thus

Thus in a watch, as the main ſpring unbends, the chain is proportionably removed from the Axis of the fuſee Wheel. In order to preſerve a regular movement, the fuſee is formed of that curve called the logarithmic curve, which correſponds to the progreſſive decreaſe of elaſticity.

III. INCLINED PLANE.—Power is to the weight, as the height of the Plane is to the length of its baſe.

IV. The PULLEY.—In a fixed Pulley, the power is equal to the weight. In this no mechanical advantage, except the conveniency of altering the direction in which the power is applied. If the ſame ſtring go round two ſets of Pullies in two blocks, the power is to the weight as unity is to the number of ſtrings at the lower block. In this the lower block is added to the weight. If each Pulley have a ſeparate ſtring fixed to ſomething immovable above, the power is to the weight, as unity is to that power of two, whoſe index is the number of moveable Pullies. Here all the moveable Pullies co operate with the weight.

Mr. White's Pullies conſiſt of two, each having many concentric grooves, whoſe diameters are in the ratio of their velocities: hence their revolutions are made in the ſame time, well calculated for deſtroying that ſhaking motion experienced in blocks of

of Pullies, from one Pulley moving so much quicker than another.

V. SCREW.—The power is to the weight, as the distance between any two contiguous threads is to the circumference described by the power.

The Screw is the strongest of all the mechanical powers; the great disparity between the velocity of the hand and that of the threads of the Screw, renders it very proper for dividing space into a great number of parts; hence well calculated for the nice adjustment of microscopes, telescopes, &c.

VI. WEDGE.—Hamilton, Desaguliers, Emerson, Muschenbroek, and Gravesand assert, that the power is to the resistance as one half the back is to the height; whilst Keil, Whiston, and Nicholson assign this ratio to be that of the whole back to the height. In both these cases it is supposed the power acts parallel to the base.

Experience does not coincide with theory. Apply a ton weight upon a Wedge and it will not penetrate, whilst the impulse of a child will make it enter. The impulse excites a vibratory motion in the constituent parts of the body, and in the instant of relaxation the Wedge enters; while in the successive instant the constituent particles meeting thus with a resistance to their re-action, exerts a force which tends to further separation.

Seventh

Seventh Mechanical Power, the SPRING.— From this, great mechanical advantage is derived in variety of inſtruments, particularly in carriages. Thus in the rough roads of Cheſhire, a pair of horſes can draw a carriage upon Springs better than four horſes could without. Springs in this caſe accumulate a kind of motion, which facilitates the progreſſive one ſimilar to flys, and vibrating balances which in clock-work accumulate the ſuperfluous power, and impart it occaſionally to equalize the motion.

FRICTION.

In proportion to the quantities of matter, and not the ſurfaces. The doctrine of Friction, Wheel, &c.

OPTICS.

Rays of Light proceed from luminous bodies in right lines and in all directions.

Whether Light is univerſally diffuſed, or emanates from the Sun, is a ſubject much controvert-

ed by philoſophers. Des Cartes, Huygens, Euler, Dr. Franklin, and many others, have ſuppoſed Light is univerſally diffuſed, while Roemer, Newton, and the generality of philoſophers deem the Sun the ſource of this fluid.

If Light were univerſally diffuſed, the ſame effects do not take place from an impreſſion as in other diffuſed fluids, " Preſſio non propagatur per fluidum ſecundum Lineas rectas, niſi ubi particulæ fluidi in directum jacent."

Roemer has aſcertained from the eclipſes of the Jovial Satellites, that Light is progreſſive in its motion; that it required eight minutes and a few ſeconds to paſs from the Sun to the Earth. Theſe obſervations have received additional confirmation from their coincidence with the celebrated diſcovery of Dr. Bradley, reſpecting the aberration of the ſtars. Light is material.

Although objections may be made to theſe experiments, which have been brought forwards as proofs of the momentum of Light, as the agitation of aſbeſtos, feathers; delicate braſs vanes, ſuſpended on harpſichord wire, being thrown into motion; yet the evident effects produced by its combination with many bodies, are great proofs of its materiality.

Franklin ſuppoſed that any particle of matter, however ſmall, moving with a velocity of near

200,000

200,000 miles in a ſecond of time, that its momentum would be equal to a 24 pounder diſcharged from a cannon.

If we ſuppoſe a luminous particle, equal in bulk to the minuteſt portion of volatile effluvia, which can be calculated, the force of motion in each particle would be infinitely inferior to the momentum of the gentleſt dew.

Light is a fluid ſui generis. Bodies may be heated from 540 degrees down to 60 degrees without exciting any ſenſible illumination; while on the contrary, we ſee Light from the ſlow phoſphoreſcent combuſtion of the lanthorn-fly and the glow-worm.

Fire is diffuſible equal, and penetrates all bodies without exception, while Light only produces ſenſible effects on opaque matter. Fire, unleſs very intenſe, produces no change in the colourleſs nitrous acid, while Light gives it another tinge, and renders it fuming.

Light blackens the oxyds of ſilver, mercury, and biſmuth, whitens the ſulphurated calx of antimony, gives the purple colours to the juice of the murex, the violet to the decoction of archil and trefoil.

Animals confined in obſcurity become white, from the Arctic bear to the larvæ of the minuteſt inſect: the tree frog, brought from its dark receſs, changes

changes from a dirty yellow to a dark green. The infant negro and native American are fairer than their parents; and their change of colour is attributed, by Dr. Bancroft, to a combination of Light with their reticular membrane.

The French chymifts, from not finding any volatile alkali or phofphoric falts in fœtal fluids, have hence fuppofed Light to be a neceffary ingredient in thefe falts.

Thus the human fpecies become pale from confinement, and Girtanner has found that pale animals and white plants are peculiarly weak.

Sometimes there appear exceptions to this, as various plants and moffes, as the *poa annua et compreffa, plantago lanceolata, tripolium anuenfe, cheiranthus cheiri.* Lichen vertrillatus are of a green colour, though growing in the galleries of mines. But Sennebier, Ingenhoufz, Rozier, &c. attribute this to the azotic and inflammable air; that the latter contains a quantity of Light, when inflammable air is joined with pure air, increafe the green colour.

Teffier has remarked that potatoes, when guarded from Light, mix their roots and young branches indifcriminately.

Plants, when expofed to Light, fecrete pure air; in the night time they evolve impure air.

The effect of Light in cryſtallization is very evident, the cryſtals are better formed ; in this caſe it appears to diſengage the electricity of the cryſtal, and thus influencing the arrangement.

The heliotropii, and many of the ſun-flower claſs, turn with the Sun, and move with that luminary ; when he is depreſſed below the horizon, the flowers cloſe their leaves, and fall into a vegetable ſleep.

The diamond and many other gems have the property of abſorbing Light, and of giving it out in the dark.

REFRACTION.

Every phyſical point of a luminous object, has rays of Light proceeding from it in every direction ; when theſe rays enter into any medium obliquely to the plane, their rectilinear courſe is changed, and bend from the right line in that point where they enter the different medium.

In thoſe tranſparent ſubſtances, which are not inflammable, this refraction is nearly in the proportion of their ſpecific gravities.

When

When a ray of light enters into a denſer medium, it becomes refracted towards the perpendicular; when into a rarer, the oppoſite.

Thoſe tranſparent ſubſtances which are inflammable, a ray of Light in its paſſage through them ſuffers a greater refraction than in the ratio of their denſities.

Thus in our atmoſphere, conſiſting of infinite aerial ſtrata of different progreſſive media, a ſolar ray meets with a continual refraction towards the perpendicular, and conſequently deſcribes a convilinear line.

In the ſame medium, however the rays of Light may vary in their obliquity, the refracted ray bears univerſally the ſame proportion to the incident ray.

A ray of Light paſſing out of air into water, when refracted the ray approaches the perpendicular in the proportion of three to four, out of air into glaſs as three to two.

This proportion always holds good, whatever may be the form of the medium.

When a glaſs is a plane ſurface, one perpendicular to any one part will be parallel to a perpendicular to any other.

When any other figure, this varies, and the perpendicular muſt be taken from that point of the curve where the ray enters.

If this curve is regular, having one and the ſame centre, the refractions in every part will ſo take place with the ſame degree of inclinations towards the axis of the lens, as to unite in one and the ſame point.

As the perpendicular line to any point is always drawn from the centre of the curve through that point, the more convex the lens, the leſs diſtance there muſt be between the circumference and the centre, and conſequently the refracted ray muſt unite ſooner in the axis.

The point where all the rays unite, is called the focus. A burning lens muſt be convex, all the Light which is thrown upon its ſurface is condenſed into a ſmall circular ſpace; the united rays produce effects in proportion to the extent of ſurface. This point varies according to the diſtance of the object from which the rays of light are evolved.

Hence it is very eaſy to calculate the focus, when there are given the diſtance of the object, the refracting power of the medium, and the radius of the curve.

If a glaſs lens be very large, by meaſuring the thickneſs of the edges and of the middle, the focal length is eaſily aſcertained. It will be as the difference between the thickneſſes of the middle and of the edge, is to half the breadth, ſo is half the

breadth

breadth to the focal length. If a glaſs ſphere, the focus will be $\frac{1}{4}$ of its diameter diſtant from the vertex. In a plano convex, the focus will be $\frac{2}{3}$ of its thickneſs nearer when the rays fall on the convex ſide, than when they fall on the plane ſide. In a very thin glaſs lens, half the breadth is a mean proportional betwixt its thickneſs and focal length.

When an object is placed before a double convex lens at any diſtance greater than the radius of the ſphere, the image will be inverted.

CONCAVE LENS.

As convex glaſſes cauſe the rays of Light to converge and unite, ſo thoſe which are concave make them ſeparate and diverge.

As concave glaſſes do not collect the rays, they have not a real focus, as the rays after they have paſſed through ſuch glaſſes do flow in ſuch a manner as that they either tend to ſome point behind the glaſs, or appear to flow from ſome point before it; theſe points are uſually called the foci.

If rays which are converging towards a focus be interrupted by a concave lens, whoſe diſtance

from the focus is equal to the radius of its concavity, after they have paſſed through the glaſs they will ceaſe to converge and become parallel.

CATOPTRICKS.

A RAY of Light falling on a mirror is reflected in an angle equal to the incident one.

If an object be placed before a concave ſpeculum at an infinite diſtance, the image will appear on the ſame ſide of the ſpeculum as the object. This is called its focus, when converging the parallel rays of the Sun. As the object approaches the ſpeculum, the image recedes; and when ſo near as to be at the centre, both will coincide; as the object paſſes the centre towards the glaſs, the image is projected towards the centre; and when but half the radius diſtant, the image is at an infinite diſtance, or proceed parallel, and the ſpeculum will ſeem to be in flames; when the diſtance is leſs than half the radius, the image appears behind the ſpeculum.

CONVEX

CONVEX SPECULUM.

THE position of images seen by reflection always appear erect, the several parts of the image have the same situation with the corresponding parts of the object, and of consequence the image appears erect.

COLOURS.

RAYS of Light have hitherto been considered as undergoing no change from refraction. Newton has shewn that a ray of Light consists of different portions, which differ in degrees of refrangibility, which portions possess colours lasting and permanent, so as not to be changed either by refraction or reflection.

When a ray of Light passes through a glass prism, that portion which is the least refracted will be red, the next orange, yellow, green, blue, purple, and violet.

It is owing to this that no convex glass can converge rays of Light to a similar point from which they originated, but forms a circle of some aberrations.

Owing to these different refractions they cannot all unite in the same point of the axis, but will form a circle of certain dimensions.

This deviation from a point is called the aberration. The space is $\frac{1}{25}$ part of the surface through which the rays of Light have flowed. These aberrations are divided into two, viz. the longitudinal and lateral aberrations.

The refractive qualities of different kinds of glasses, with respect to the divergency of colours, are not in the same degree of ratio.

This property was first ascertained by Mr. Dollond, who found that white flint glass dispersed the rays, after refraction, one-third more than crown glass.

Two wedges of glass, one of flint of twenty degrees, and the other of crown of thirty degrees, the Light would be refracted but not coloured.

By combining in this proportion a convex glass of crown, and a concave one of flint, there would be a refraction without any colouring; as the excess of refraction is in the convex, the rays of Light would be converging.

RAINBOW.

Aristotle knew it was produced by watery drops; he thought a ſingle particle was too ſmall to reflect the whole image of the Sun: hence, he ſays, the colour is only exhibited, and not its proper figure.

Seneca and Vitellio ſuppoſed the colours of the Rainbow to be three, and produced by a mixture of the brightneſs of the Sun's Light with the blackneſs of the cloud from which it is reflected. Porta thought the Rainbow produced by the refraction of Light in the whole body of Rain or Vapours, but not in the ſeparate drops.

In 1571, Fletcher of Breſlaw, endeavoured to account for theſe colours, by means of a double refraction and one reflection; he did not imagine that theſe circumſtances took place in one drop, that it ſuffered a refraction at its entrance and at its exit, and was afterwards reflected by another drop before it reached the eye.

In 1611, Antonio de Dominis, a biſhop, firſt advanced that the double refraction of Fletcher with an intervening reflection, were ſufficient to produce

produce the colour of the Bow, and to bring them to the eye of the ſpectator.

Not knowing the different refrangibility of the coloured rays, he endeavoured to explain theſe colours by ſuppoſing the red rays had traverſed the leaſt ſpace in the inſide of a drop of water, and therefore retained more of their native force, and produced a ſtronger ſenſation: he had alſo obſerved that one drop ſends one colour to the eye, another drop another colour, as the eye was not wide enough to receive rays of all colours from the ſame drop.

As all the rays of ſimilar colours muſt leave the drop of water in a part ſimilarly ſituated with reſpect to the eye; hence each of the colours muſt appear circular.

The external Bow he imagined was formed by the higher part of the Sun's diſc, and the interior Bow by the lower part.

Des Cartes ſhewed the outer Bow was produced by two reflections and two refractions in the ſame drop of water.

Newton, after aſcertaining the refrangibility of the coloured rays, applied his reaſoning to the explication of theſe phænomena.

The moſt refrangible rays form an angle with the Sun and the eye, of 40 deg. 17 min. and the leaſt refrangible rays of 42 deg. 2 min. in order

to

to conſtitute the lower Bow; the difference will give the width by conſidering the Sun as a point, as it ſubtends an angle of 30 minutes, this muſt be added to it.

In the ſuperior Bow the leaſt refrangible rays will have an angle of 50 deg. 51 min. and the moſt refrangible 54 deg. 7 min. As theſe angles are reverſed, the colours muſt be alſo; and hence the diſtance between the Bows will be 8 deg. 49 min.

Sometimes a third Rainbow has been ſeen. Celſius deſcribes one larger than the other two, and interſecting them. Mr. Edwards ſaw one ſome time after the Sun had ſet.

Halos or Corona, are luminous circles ſurrounding the Sun, Moon, and Planets, varying in their ſize or extent. Muſchenbroek ſays, in Holland fifty may be ſeen in a day. Des Cartes imagined they were produced by the refraction of Light in round particles of ice floating in the atmoſphere. Gaſſendus ſuppoſed it was owing to the ſame cauſe as Rainbows.

Huygens invented a laboured hypotheſis, which has been adopted by Newton and Smith. Theſe ſuppoſed there were in the atmoſphere tranſparent bodies with opaque nuclei, formed by ice without and ſnow within.

Halos

Halos or Coronas we may form at pleaſure, by placing a candle in the midſt of ſome ſteam, or beyond a receiver during the proceſs of exhauſtion, and viewing the Light through the cloudy precipitation.

PARHELIA, OR MOCK SUNS.

ARISTOTLE mentions two, Scheiner ſaw four at Rome which were the firſt that excited the attention of philoſophers. Muſchenbroek ſaw the ſame number at Utrecht, and in 1661 Hevelius ſaw ſeven at Sedan; their apparent ſize, equal to the true Sun, are externally tinged, and many have a fiery tail. Dr. Halley mentions one with tails each way.

Sometimes three Suns have been ſeen in the ſame vertical circle, well defined, and touching one another, the true Sun in the middle.

In 1771, Mr. Baxter at Fort Glouceſter in America, on January 22d, the froſt ſevere, ſaw five; at firſt he obſerved a large circle round the Sun, with two Parhelia as brilliant as the original Sun; a little more than one-third from the horizon

zon to the zenith a beautiful enlightened circle parallel to the horizon, which went quite round, till the two ends met in the circle ſurrounding the Sun; directly oppoſite to the Sun a luminous croſs, and in its interſections a Mock Sun; near the zenith was a beautiful Rainbow, with its convex ſide oppoſed to the Sun.

Theſe phænomena are attributed by Dechales to reflections of the image of the Sun, from clouds properly figured and well defined.

PARASALENES

Are ſimilar phænomena reſpecting the Moon.

EYE.

The parts of the Eye neceſſary for explaining the manner of viſion deſcribed. The Cornea, the Aqueous Humour, the Iris and Pupil, the Cryſtaline Lens, its ſurrounding Capſule, and the Ciliary Zone, the Vitreous Humour, the Retina, Pigmentum, Choroid Coat, and the Optic Nerve.

A ray of Light coming from a luminous body, or reflected from any object, falls in ſuch a manner

ner upon the Tunica Cornea of the Eye, as to form a ſharp cone between the lucid point and the membrane on which they are ſpread. The Cornea, by being ſpherical, admits of an infinite number of perpendicular rays, whilſt if it had been of a plane ſurface, could only have admitted of one; on this account viſion would have been much limited, for rays would then have entered ſo obliquely, inſtead of being refracted would have been reflected.

In inſects who are deprived of motion of the head, is beautifully reticulated, each portion being a part of a diſtinct ſphere, in order to produce a quick convergency of ſurrounding rays. In flies it is eaſy to count three thouſand interſtices. Lewenhoek imagined they were ſo many diſtinct Eyes; there is only one Cryſtalline Lens common to them all.

The Cornea itſelf being a meniſeus glaſs, like all media of a curvilinear nature whoſe correſponding curves are concentric, the refraction in the entrance is ſo corrected by the refraction in the exit, as to render the emergent ray in the ſame line of continuation with the incident one.

As between the Cornea and the Iris there is interpoſed a fluid of nearly the ſame denſity with water, this renders the Cornea a plane convex Lens,

Lens, which form causes the rays to converge after their entrance.

The Aqueous Humour, by being fluid, allows of a free and easy motion to the dilatation and contraction of the Pupil. Fishes have a very small portion of this fluid, in them it would be useless, as they are surrounded by an equally dense medium.

The rays thus gently converging, pass through the perforation of the Iris, called the Pupil, which in all animals intended to see equally every way is orbicular, a form which allows of the transmission of the greatest quantity of Light in the least space. In the Iris of a greyhound, the two range of muscular fibres are very visible, one order radiated, and the other orbicular concentric to the Pupil; the former by contracting dilate the Pupil, the latter diminish it.

These fibres are exquisitely sensible, and preserve the Retina from being too much injured, by thus regulating the intensity of Light.

It is by this we distinguish whether a cataract or opaque crystalline be combined with a Gutta Serena; if we observe no coincident contraction of the Iris of the diseased Eye from the sympathising influence of the other, the removal of the Crystalline would then afford no relief.

If

If this fibrous contraction were in the proportion of the weakeſt Light to the ſtrongeſt, the degrees of contraction would then be one million of times; the faint glimmering of a diſtant candle to the unclouded rays of the meridian Sun is as 1 to 1,000,000.

Some animals have a voluntary power over the Pupil, as the cat, &c. Dr. Goddard tells us that the camelion not only can dilate one without contracting the other, even look upwards with one Eye, while downwards with the other.

The rays, after having paſſed through the Pupil, enter the Cryſtalline Lens, a medium of a denſer nature, and beautifully formed of two elliptical convex portions, the anterior flatter than the poſterior, compoſed of concentric Lamina, the external Lamina being of a ſoft mucilaginous nature, the interior more compact, till at laſt they form a ſort of continued Nucleus.

The ſpecific gravity of the whole Lens is leſs than the ſpecific gravity of the Nucleus. This different denſity of the conſtituent parts is admirably contrived for correcting the aberration from its figure, as well as of the Cornea, &c. The rays in each pencil are more and more remote from the Axis, by paſſing through a medium gradually diminiſhing in denſity from the middle towards the extremes, have their foci gradually

dually lengthened, which corrects the aberrations of the figure, that ſo they may all unite nearer together.

The aberrations ariſing from figure of a ſmall Lens is inconſiderable to the aberrations cauſed by the unequal refrangibility of the rays of Light.

Euler ſuppoſed the Eye perfectly achromatic, while Dr. Maſkelyne has attempted to calculate the circle of aberrations upon the Retina to be .002667 of an inch; he thinks ſome ſuch aberration neceſſary to account for the ſenſible diameters of ſome of the fixed Stars.

The rays, after paſſing through the Cryſtalline enter the Vitreous Humour, which being nearly of a ſimilar denſity, produces no alteration in the refraction.

Its uſe ſeems principally to preſerve the ſpherical form of the Eye, and to keep the Retina at an equal diſtance from the Cryſtalline.

The rays of Light converge in the very points they emerge from the Vitreous, which is immediately covered by the expanſion of the Optic Nerve, termed the Retina.

The Retina, when examined by a high magnifying power, appears like a piece of pluſh, with the ends of the threads turned towards the Cryſtalline.

A circle facing the Eye, ſubtending an angle of one minute, its diameter on the Retina will be $\frac{1}{5340}$ of an inch, ſuppoſing the interſection of the rays to be juſt as they emerge from the Cryſtalline; this coincides nearly with the intervals between two fibrils.

Thoſe who can ſee remote objects more diſtinct than others, have the intervals between the fibrils leſs. Muſchenbroek informs us of one man who could count 13 Stars in the Pleiades, and Mæſtlinus could diſtinguiſh alſo with the naked Eye, three Satellites of Jupiter.

How to aſcertain Diſtance.

If the admeaſurements of the different parts of the Eye given by Monſ. Petit are correct, perfect viſion will be at 24 inches. Rays of Light proceeding from this diſtance will be converged on the Retina, without any alteration of the Eye.

If the object ſhould be nearer, the rays of Light would be more diverging, and would not be converged on the Retina without ſome change in the Eye; ſo Light from objects remotely ſituated, by being parallel, would be converged too ſoon.

To make the requiſite change, the muſcles ſurrounding the Eye, or any alteration of the Cornea, would be inadequate; if the exterior curvature

ture of the Cryſtalline Lens be rendered equally convex with the poſterior. Rays of Light from near ſituated objects would be converged; if the poſterior curvature ſhould be reduced to an equality with the anterior, parallel rays would be converged.

In theſe changes the ſurrounding Capſule would occaſionally become corrugated; this is prevented by the Ciliary Zone, which by its occaſional contraction prevents this.

In fiſhes nature makes the change only in this part; thoſe who have ſuffered an extraction of this Lens, are obliged to make uſe of glaſſes of different convexities, proportioned to the diſtances.

The mind, from experience, aſſociates the diſtance of the object with theſe reſpective changes, as far as theſe occur, forms an idea of the remoteneſs or proximity of an object.

Marriotte finding a piece of paper is loſt to the Eye, whoſe diameter is about the tenth part of its diſtance from the Eye; the angle thus formed by the interſected ray and the internal baſe, correſponds to the diameter of the Nerve: from the inſenſibility of this part of the Retina, he hence imagined the choroïdes was the ſeat of viſion.

The Near-ſighted and Long-ſighted Eye.

The Eye, like other parts of the human body, from any continued uniform action, acquires permanently that ſtate as to be with difficulty changed; thus ſailors, countrymen, travellers, &c. from looking at remote objects, become long-ſighted, and with difficulty can accommodate the Eye to near ſituated objects: ſo on the contrary, ſtudents, watch-makers, &c. become near-ſighted. The former is more generally the reſult of age, ariſing from the general reduction of the whole ſyſtem, the Eye participating of it, no longer preſerved in its full orbicular form, no longer the uſual animating convexity, ſinking within the orbit, the powers of convergency are thus diminiſhed, a glaſs of a proper degree of convexity muſt be adopted.

So the near-ſighted is more frequently congenite, to remedy which a concave glaſs muſt be uſed.

*Theory of Spectacles.**

Strabism or ſquinting is of two kinds, one ſpecies of it curable.

Impreſſions on the Retina remains a certain time; obſervations of Newton and Biſhop of Llandaff.

Inflection of Light.

Why Stars ſcintillate.

The circulation of blood in the Eye rendered viſible.

Ocular Spectra, an examination of De la Hire and Dr. Robert Waring Darwin's opinions.

An enquiry into the ſingular terreſtrial refractions, termed by ſailors Looming, the obſervations of Ellicott and Coxe.

The advantages of two Eyes; objects not only appear a little brighter, cannot be loſt to both Eyes at once; for when the image of an object falls upon the Optic Nerve of one Eye, it will fall at ſome diſtance from it in the other; alſo the field of viſion is conſiderably increaſed.

* The Rev. Mr. Stark, in the Iriſh Memoirs, thinks defective ſight may in ſome reſpects be owing to the want of that gradation in the denſities of the parts of the Cryſtalline; he recommends a concavo-convex glaſs, whoſe greater curvature is on the convex ſide.

The effects of motion; a ſmall object in motion is eaſier diſcerned than if at reſt. A Star is ſooner perceived by agitating a little the teleſcope.

The luminous appearance of the Eyes of animals with dilated Pupils, as cats, owls, &c. is owing to the Pigmentum not being black; the rays are reflected from the concave ſurface, and unite in a point on the poſterior part of the Cryſtalline Lens; thus being placed nearer to the Lens than its focal diſtance, the rays continue diverged and diffuſed, and thus illuminates the Lens.

White animals have no pigmentum, the redneſs which is ſeen is from the choroïd veſſels turged with blood; when the animal dies the redneſs diſappears, from the choroïd veſſels collapſing.

MICROSCOPES.

By these instruments we are enabled to examine the minute and wonderful works of the creation, to unfold the admirable structure of animals and vegetables, and display the exquisite texture of their constituent parts.

The ancients were acquainted with the burning power of glasses; the surgeons with glass spheres used to cauterise wounds, and vestal virgins thus kindled their sacred fire.

The specula of Julius Cæsar and of Ptolemy, were only watch-towers.

Friar Bacon and Alhazen seem to have been acquainted with the magnifying powers of glasses; he mentions how he could make a boy appear like a giant, and a man a mountain, and the celestial luminaries to descend in any direction.

Although the magnifying power of a single Lens might be known to Bacon, the application of a small Lens to the examination of bodies took place in the 16th century. Fontana lays claim to it in 1618, some say Zachary Jansen and others Drebelius, who first made compound Microscopes.

 Thus

Thus a ſimple Microſcope conſiſts of a ſingle ſmall convex Lens, interpoſed between the Eye and the object. The magnitudes of objects are regulated by the diſtance they are from the Eye; if an object is placed at one inch from the Eye, the appearance is confuſed and indiſtinct, the rays are too diverging to be converged by the Eye; if a convex Lens, whoſe focal diſtance is one inch, the rays after being refracted will enter the Eye parallel; if eight inches be the neareſt point of perfect viſion, by means of the glaſs it will be ſeen eight times nearer, and conſequently enlarged eight times every way. If $\frac{1}{20}$ of an inch, the object will be 160 times nearer, and conſequently its ſurface 25,600 times greater.

Theſe Lewenhoek made uſe of. Mr. Gray invented a little glaſs ſphere, filled with water; he alſo perforated a piece of lead with a pin, and placing a drop of water on it, he could ſee any animalcule which might be in.

Compound Microſcopes.

WHEN there is more than one Lens is thus termed.

In this caſe the image of the object is viewed, and not the object. The object is placed farther from the Lens than the focal diſtance, ſo that after

ter refraction the rays converge, aud where they unite, the image of the object is formed; this image is viewed through a convex Lens, ſo placed that its focus ſhall be the place of the image.

This combination increaſes the field of view; ſtill further to increaſe this, a ſecond and a broader eye-glaſs is placed between the two others, which converges the rays from the object-glaſs much ſooner.

When theſe were firſt uſed, they were held in the hand, the object illuminated by the window; Culpepper added the reflector. For viewing opaque objects, we are indebted to Mr. Lieberkulen, by means of a ſmall concave reflecting mirror, perforated in the centre, in which the object Lens is placed.

Solar Microſcope,

Is a Wilſon's Microſcope, the object ſtrongly illuminated by the Sun, the rays concentrated by a convex Lens, invented by Mr. Lieberkulen; Æpinus added the mirror. The object thus being ſtrongly illuminated, will bear with diſtinctneſs a conſiderable magnifying power, which will be as the focal diſtance of the glaſs to the diſtance of the Screen.

TELE-

TELESCOPES.

THE invention of these useful instruments was casual, to whom it should be ascribed authors differ, some give it to Metius, a Dutchman, about 1609; others to Lippensheim, of Zeland, a spectacle maker, from casually holding two convex spectacle glasses in a certain position; Borellus gives it to Zacharias Jansen. Fifteen years before any of these, Baptista Porta gave some sketches.

The first were about one foot and a half. Galilæo from the confused report made one, as being the first who philosophically employed it, by many has been deemed the discoverer; the first he had, magnified only three times, the next eighteen, afterwards one thirty-three, with which he discovered the Satellites of Jupiter, and the spots on the Sun's surface: the Telescope he used was a convex glass and a concave one.

The principles of a Telescope and Microscope are the same; as Telescopes are intended to view remote objects from whence rays proceed parallel, an object glass of a small degree of convexity is sufficient.

Father Scheiner first made use of two convex glasses, from an hint of Kepler's; in this terres-

trial objects are neceſſarily inverted, will appear diſtinct, and with a conſiderable field of view. The magnifying power will be in the ratio of the focal length of the object-glaſs to the focal length of the eye-glaſs, the ſame whether the eye-glaſs be concave or convex.

Rays proceeding from the eye-glaſs to the Eye are nearly parallel, a direction proper for to be converged on the retina in the natural Eye; to the near-ſighted perſon the eye-glaſs muſt be put in nearer the object-glaſs, in order to render the rays after their emergence a little diverging.

When a number of eye-glaſſes are uſed, the field of view is increaſed, although the number of refractions are greater, yet the ſum of the aberrations ariſing from the figure is leſs.

Although each Lens has its image, either real or imaginary, yet in general there are only two real ones, the firſt inverted, the ſecond upright. When the number of real images is even, the object will be ſeen upright; when that number is odd, the object is inverted.

All that is eſſential, is that the rays of the ſame pencil which enter parallel, ſhould emerge parallel; the intervals and focal lengths of all the Lenſes, except one, may be aſſumed at pleaſure, from whence that one muſt be determined.

Imper-

Imperfections of Glasses.

The principal imperfections are two, one arising from the figure of the glass, the other from the different refrangibility of the different colours.

Aberration arising from Figure.

When a convex glass is formed of curves which are portions or segments of a sphere, the rays of Light which fall near the edges of the Lens are sooner converged than those rays which fall nearer the Axis; hence between these extremes there will be a number of images.

The larger the segments the greater their diffusion. On this account some opticians limit the arch to twenty degrees of its respective circumference. For the object-glass of a Telescope this is too great, although the dispersion of the rays might be very small, the magnifying power multiplies it as often as the object itself.

This aberration is but inconsiderable to that which arises from the different refrangibility of the prismatic portions.

Philosophers, previous to the time of Newton, attributed this to the figure of the Lens. When

Des Cartes ſhewed that glaſſes figured according to the ſurface deſcribed by conic ſections turned about their axis, would not have that effect,* then mathematicians turned their attention to grind glaſſes of ſuch forms, and among the reſt Newton himſelf, till his diſcoveries in 1668.

If a red object is placed at a diſtance from a convex Lens, the image will be farther from the Lens than if the colour of the image had been violet; the diſtance between theſe two images would be the meaſure of the aberration; if the object is of an heterogeneous colour, this ſpace will be filled by images of the intermediate colours.

This diſperſion is about the $\frac{1}{28}$ part of the focal diſtanee, a Lens of ſeven feet focal diſtance, the diſperſion would be about three inches.

The error ariſing from this diſperſion, is to that from the aberration of the figure as 5449 to 1. The diameter of the circle in the middle

* Des Cartes, in his Dioptrics, demonſtrated that if the foci of two oppoſite hyperbola, whoſe axes were in the ratio of the ſines of incidence to refraction, if one of theſe hyperbolas be turned about its axis, and a portion of the ſolid ſo generated be cut off by a plane perpendicular to the axis, then all the rays which fall perpendicular upon this plane will be refracted by the convexity on the oppoſite ſide to one and the ſame point.

ſpace

ſpace between theſe two foci is about the 55th part of the diameter of the aperture of the glaſs; and were it not that the orange, yellow and green occupied the central part, and being the moſt vivid, objects would not appear in the leaſt diſtinct. Hence the greater the focal diſtance of the object-glaſs is, the leſs muſt be the proportion which the focal diſtance of the eye-glaſs may bear to that of the object-glaſs; as the degree of confuſedneſs is as the breadth of the object-glaſs, ſo the magnifying power of the eye-glaſs muſt be in that degree.

Thus an object-glaſs of four feet focus will admit of an eye-glaſs of one inch, and conſequently magnify forty-eight times. An object-glaſs of forty feet focus will only admit of an eye-glaſs of four inches focus, and only magnifies 120 times; and one of 100 feet will only bear one of 6 inches, and this only magnifies 200 times.*

On this account Newton deſpaired of improving refracting Teleſcopes, and hence turned his attention to reflecting Teleſcopes.

* If the aperture of an object-glaſs be not as the ſquare root of the power of magnifying, the image will want Light; the ſquare root of the power of magnifying will be as the ſquare root of the focal diſtance of the object-glaſs, and therefore the focal diſtance of the eye-glaſs muſt be only as the ſquare root of that of the object-glaſs.

Euler tried by making the object-glaſs of two materials to correct this refraction; the diſcovery was reſerved for Mr. Dollond in 1757, who demonſtrated that the diſperſive powers in different glaſſes were not the ſame; thus flint glaſs diſperſes more than crown glaſs. Mr. Zeiher of Peterſburg attributes this to the minium it is combined with; he proceeded in the manner already ſhewn in the analyſis of convex Lens.

Reflecting Teleſcopes.

MERSENNUS firſt ſuggeſted them to Des Cartes, who treated the idea as ridiculous. Mr. Gregory, of Aberdeen, has been deemed the inventor, this he propoſed in 1663, viz. a concave ſpeculum, reflecting the rays from an object towards a ſmall ſpeculum, and this returning the image to an Eye placed behind the great ſpeculum; Newton was a workman, five years after he began one, and in 1672 completed two ſmall reflectors. The Academy of Sciences endeavoured to depreciate Newton by a diſguiſed Gregorian Teleſcope, under the name of Caſſegrian, with this difference, the ſmall ſpeculum was convex.

Thoſe Newton made were only ſix inches long, yet magnified equal to a ſix feet refractor; the difficulty of poliſhing made near forty years elapſe

elapſe before another was made. Thus Mr. Hadley made one five feet long, after the Gregorian manner, and now from the improvement of Mr. Short and Mudge, a good poliſh alſo the proper parabolic figure are now given.

The powers of magnifying are as the focal diſtance of the large concave ſpeculum exceeds that of the eye-glaſs.

Newton's reflector was inclined to an angle of 45 degrees to the axis of the larger, in this not ſo great a quantity of Light is loſt; on this account Dr. Herſchel has adopted it.

Binocular Teleſcopes. Dr. Blair's Teleſcopes. Opera Glaſs. Magic Lanthorn. Camera Obſcura. Hadley's Quadrant, &c.

PNEU-

PNEUMATICS.

The ſcience of Pneumatics, in the original derivation of the word, implies an inveſtigation into a ſomething of a ſpiritual nature: in this point of view the ancients conſidered that vaſt aerial volume that ſurrounds us, they ſuppoſed it a principle diveſted of the common properties of matter. Ariſtotle ſeems to have been the firſt who aſcribed Gravity to Air, the demonſtration of which was reſerved for Galilæo, Torricellius, and Merſennus.

All the philoſophers, till within this century, imagined that there were only one kind of aerial fluid, and that its various ſtates depended on the admixture of extraneous ſubſtances: thus Van Helmont was acquainted with the inflammable qualities of ſome Vapours, and knew that others extinguiſhed flame and ſuffocated animals; he had no idea that theſe ſubſtances were capable of being ſeparately exhibited in the form of a permanently elaſtic Vapour not condenſible by Cold.

Boyle obſerved that the elaſtic fluid extricated from ripe fruits, fermenting and effervecing liquors, extinguiſhed Flame, &c.

The ſagacity of Newton had obſerved that there were a ſomething in common Air neceſſary to Life, and which he called the ſpiritual part, and conjectured that Comets might occaſionally renew what was deſtroyed by reſpiration. Dr. Hales firſt collected Air under receivers; he found that mineral waters owed their ſpirit and briſkneſs to the Air united with them; he thought it was the ſame as atmoſpheric Air; he could not imagine that what ſhould be the ſource of briſkneſs in mineral waters, could be the ſame Mr. Boyle had found deſtructive to animals. Theſe were more particularly unfolded by Dr. Browning.

Dr. Black firſt pointed out the effects ariſing from depriving bodies of Air united with them, uſually called fixed Air, and how their cauſticity was deſtroyed by adding it to them. Since then Prieſtley, Cavendiſh, Scheele and Lavoiſier have clearly demonſtrated the exiſtence of many diſtinct and eminently elaſtic fluids.

Vital Air,

Termed by Prieſtley, dephlogiſticated Air; by Lavoiſier, oxygenous Gas, from its being the Baſis of all Acids. The Air we breathe is formed of 28 parts of this Gas, with 72 parts of impure

pure Air, which being destructive to Life, is called azotic Gas.

When a Light is placed under a receiver, it will keep burning as long as there is any portion of pure Air; so metals, when calcined, are nothing more than an union with this Air, hence are said to be oxydated; they then lose their metallic splendor, their malleability, from being rendered soluble, become poisonous; in consequence of this union they have a proportional increase of weight. Light will disengage this Air from many Acids, and from Vegetables. This last Mr. Cavendish attributes to the decomposition of Water.

Vital Air is heavier than Atmospheric Air; a cubic foot of Atmospheric Air weighs 720 grains, of Vital Air 765.

The respiration of this Air is supposed by Dr. Crawford to be the source of animal heat; when Air has been respired, it becomes changed, being converted into fixed Air, and its capacity for Heat being then so much less, what was evolved in the change has been deemed a sufficient source.

The theory of Dr. Crawford, respecting the capacities of bodies for Heat, shewn in many respects to be imperfect.

The medicinal properties of this Gas confidered, Scheele, Chaptal, Cailliens, and Dr. Beddoes' opinions.

Azotic Gas

Lighter than oxygene Gas.

A cubical inch weighs 0.4444 of a grain: this Gas is the bafis of Nitrous Acid, hence by Dr. Pearfon has been termed Nitrigen Gas: if to 20½ parts of azot. 43½ parts of oxygen be added, 64 parts of nitrous Gas are formed; if to this we join 36 parts of oxygen, 100 parts of nitric Acid refult from the combination; and when this laft acid is united with Potafh, Nitre or Salt Petre is formed.

Nitrous Air

Was firft difcovered by Dr. Hales, who in examining the Air that was difengaged from the Walton Pyrites, by means of Spirit of Nitre, obferved that when joined to common Air, an abforption of part of the common Air enfued. Dr. Prieftley extended thefe experiments, procuring the fame Air from Aq. Fortis poured on any of the metals, as iron, copper, brafs, filver, &c. he found it produced no diminution in any part

part of the Airs but pure Air: he hence ufed it as a teft for the purity of Air; the graduated inftrument he ufed, he called an Eudiometer.

Nitrous Air being the fame as nitric Acid, deprived of a portion of its oxygen, hence when the acid is poured on metals, thefe are calcined by the oxygen of the Acid, the remaining portion of the Acid becomes aeriform.

Carbonic Acid Gas

Has been the longeft known; Van Helmont called it Gas Sylveftris, becaufe produced in vaft quantities during the combuftion of charcoal: it was formerly called fixed Air. It exifts ready formed in chalk, marble, and all the calcareous ftones neutralized by lime. From thefe it is eafily difengaged by fulphuric Acid: this Gas is the heavieft of all, a cubic foot weighing 807.34 grains. It is a compound refulting from an union of Carbon and oxygen Gas; when charcoal and metallic oxyds are combined in proper proportions, the oxygen of the oxyd combines with the carbon forming this Gas, and the metal recovers its reguline ftate; this has been elegantly analyfed by Mr. Smithfon Tennant, by mixing together fome powdered marble flightly calcined, and fome phofphorous, in a glafs tube well clofed

 and

and luted, and then kept in a red heat for a few minutes when cool, a black powder is formed, which consists of charcoal and phosphat of lime.

This Gas unites with about its own bulk of Water, and acidulates it: this is the cause of briskness in Pyrmont Waters; it arises in abundance from fermenting liquors. Air after it is respired is converted into this Gas; it is often found in mines and subterraneous places called choke damp. It was thought this was the Air in the celebrated Grotto del Cano: Spallanzani proves it to be azotic Gas.

It has the property of retarding putrefaction; whether this arises from the carbon might be a subject of enquiry?

Hydrogene Gas.

THIS Gas was usually known by the name of inflammable Air; it is evolved from all putrid animal and vegetable matters: since the decomposition of Water has been ascertained, this fluid being found its principal source, hence has acquired the name of Hydrogene. It is the lightest of all the Gases, a cubic foot only weighing 41 grains: one hundred grains of water is found to be composed of 85 grains of oxygen Gas, and 15 grains of hydrogene Gas.

It

It is found in mines, and often produces the most dreadful effects; is called wild-fire. By being so specifically light is the reason why balloons are so buoyed up.

This Gas is easily procured by dissolving iron or zinc in diluted vitriolic Acid; the Water is decomposed with rapidity: this Gas united with azot forms the volatile Alkali; these constitute the ammoniacal smell observable in putrescent substances.

When medicinally used, by being mixed with about twelve times its bulk of common Air, alleviates irritations of the lungs.

With this Air Dillier exhibited his beautiful fire-works, varying its colours by different admixtures: thus inflammable Air of pit-coal, mixed with $\frac{1}{3}$ of the Air of the lungs, makes a blue flame with nitrous Air, green, &c.

Fluoric Acid.

MARGRAFF discovered this Acid ready formed by nature in the fluoric spars, combined with calcareous earth, so as to form an insoluble neutral salt; it is disengaged by the sulphureous Acid, as it dissolves glass and siliceous substances, metallic vessels must be employed. From this circumstance it is that beautiful etchings may be

 made

made on glaſs, as on copper, with the nitrous Acid; if we cauſe the fluoric Acid to paſs over into a recipient of water, it is condenſed and abſorbed by the Water.

By an attention to theſe elementary principles, the various changes which take place in animal and vegetable ſubſtances are eaſily explained: thus when an animal is deprived of Life, deprived of that active principle which preſerved theſe elements in their proper balance, the equilibrium is broke, the whole ſubſtance becomes perfectly analyſed, and nothing but a mould left behind; the hydrogene, one of the component parts of the circulating fluids, uniting with the azotic principle of the diſſolved animal fibre, from acquiring ſufficient caloric, to aſſume a gaſeous form, conſtitute the ammoniacal ſmell; the oxgen and carbon eſcape in the form of carbonic Acid, theſe four being the elementary parts of an animal.

Preſſure and Elaſticity of the Air.

THE Atmoſphere, principally formed of aerial particles, of Caloric, of Electricity and of Magnetiſm, being univerſally full, on this general plenum the phænomena of preſſure and of elaſticity depend.

If

If a pneumatic receiver could be formed of ſuch materials that neither Air, Fire, Electricity or Magnetiſm could permeate, then the proceſs of exhauſting the Air would be impracticable.

As we know of no body but what ſome of theſe ſubſtances will permeate, the phænomena which are produced by exhauſtion ariſe only from a change of place.

As Air cannot permeate a glaſs receiver, this elaſtic fluid may be drawn out; every exhauſtion of the Air from within when thrown into the general atmoſpheric maſs, muſt neceſſarily occupy a certain ſpace; as there is a plenum without, unleſs it can force by its preſſure an adequate bulk of Fire into the receiver, the reſiſtance to the exhauſtion would exceed every poſſible effort.

Every part of the receiver being permeable to Fire, an equal bulk of this principle immediately enters in.

The receiver is as full after the Air is withdrawn as before, of another principle.

A thermometer placed under a receiver from this circumſtance ſinks in proportion to the exhauſtion. As the receiver is ſurrounded by a fluid which cannot enter in, will be acted upon in proportion to its extent of ſurface; the reaction will be exactly equal to the force employed in the aerial exhauſtion.

This

This preſſure in an exhauſted receiver is as fifteen pounds on every ſquare inch.

The caloric within ſide the receiver is no ways a counteracting preſſure to the Air without; like water diffuſed in the vaſcular ramifications of ſponge, on the ſlighteſt preſſure paſſes through the receiver in every direction.

The Atmoſphere, formed by a combination of theſe different principles, acts as other fluids with reſpect to preſſure, in proportion to the perpendicular height.

As that portion of the Atmoſphere which is contiguous to the Earth is preſſed upon by that above, it will be in a comparative ſtate of condenſation; thus the denſity will diminiſh in the inverſe ratio of the columnar height.

What this ratio is, will be more particularly noticed when on Barometers.

Elaſticity of the Air.

Elasticity of the Air is not to be conſidered as any power peculiar to this fluid, or any kind of ſpring in its conſtituent particles, nor any ways different from that which is poſſeſſed by other fluids.

If at the bottom of a column of Mercury I place ſome Æther, the laſt rapidly riſes up; its ſpecific

ſpecific gravity, ſo much inferior to that of Mercury, yields to the preſſure all around, and riſes up with a velocity in the ratio of the difference of their denſities.

So Air, if in a different ſtate of denſity than the Atmoſphere, in the proceſs of equalization, evinces that power called by the term Elaſticity.

A ſmall quantity of Air included in a bladder cannot occupy a larger ſpace when ſurrounded by the Atmoſphere. When the denſity of the ſurrounding Atmoſphere is any ways diminiſhed, then the ingreſs of caloric into the Air in the bladder, takes place with that in the receiver, and thus becomes diſtended.

As Air of equal denſities undergo theſe changes equally, any portion of Air, however ſmall, will be equal to the atmoſpheric preſſure: it is preciſely in that ſtate in which it would be if unconfined.

Thus Air preſſing on a bladder tied over a receiver, or on the outer ſurface of a ſquare bottle, produces no effect, becauſe the Air within is an exact counterpoiſe to the Air without; abſtract this internal Air, and the preſſure of the outer Air will be ſoon evinced.

So if the outer Air be removed, the internal Air receiving additional caloric, will evince ſimilar power. The *Elaſticity* of Air is then equal to the preſſure.

Con-

Condenſation.

All bodies, of whatſoever kind, can undergo no change with reſpect to their bulk, without the medium of ſome other principle, as Caloric, Electricity, &c.

If one hundred cubic inches of Air be reduced to a ſpace of fifty inches, fifty cubic inches of Caloric, Electricity, &c. are diſengaged.

When Air is condenſed in a braſs ball, through the medium of a ſtrong glaſs tube, and a pair of ſenſible pith balls ſuſpended on the braſs, in the firſt proceſs of condenſation theſe diverge with poſitive Electricity.

The different gaſes give out different quantities. As the condenſation continues, caloric is given out, the ball becomes conſiderably heated. Theſe circumſtances demonſtrate, that in thus forcing the conſtituent particles of Air into a ſtate of greater approximation, the caloric and Electricity which are diſſeminated in the interſtices of theſe particles are forced out, and eaſily paſs through the ſubſtance of the braſs.

When this condenſed Air is ſet at liberty in reſuming its original ſtate, Electricity and Fire are rapidly abſorbed; pith balls diverge with negative Electricity, and a conſiderable degree of coldneſs is induced in all contiguous bodies.

In

In the fountain of Hiero, conſtructed on a large ſcale at the Chemnicenſian Mines in Hungary, the Air in a large veſſel compreſſed by a column of water 260 feet high, a ſtop cock is then opened, the Air iſſues out with great vehemence, becomes greatly expanded ; ſo much cold is produced, that the moiſture from the ſtream of Air is precipitated in the form of ſnow, and ice is found adhering to the noſel of the cock.

In damp weather a common glaſs globe will bear the condenſation of three Atmoſpheres ; when thus left on the return of a fine day generally breaks, not being able to bear the additional quantity of Caloric and Electricity which the Atmoſphere has acquired.

Air-Pump.

Otto Guericke, mayor of Magdebourg, firſt exhauſted a receiver, placing it on water, and pumping the Air out. Mr. Boyle was the firſt who exhauſted it by means of a piſton moving in a barrel and a valve ; there being only one barrel, the preſſure of the Atmoſphere was very great. Papin and Dr. Haukſbee removed this difficulty by adding another, ſo that the preſſures counteract each other.

Mr. Vream changed the alternate up and down motion into a circular one.

In these the valve covering one large hole, and the piston not accurately covering the bottom, prevented any great exhaustion. To remedy this, Mr. Smeeton, in 1752 made seven small holes, instead of one large one, that the valve might be easier raised up, and caused the piston to go down to the bottom.

Even in this the Air when rarefied to a certain extent, is incapable of raising the valve; one of this construction rarely exhausts more than 3 or 400 times. Mr. Haas, by a pedal contrivance to raise up the valve, was capable of exhausting 1000 times.

The most perfect form is the Air-pump of Mr. Cuthbertson, where instead of a valve he has a brass cone with fifty or sixty leathers, sliding into a hollow cone; in this, exhaustion has been carried to 2400 times.

To estimate the number of strokes requisite for any exhaustion, the capacities of the piston and receiver being known, the calculation is very easy.*

BARO-

* If the capacity of the barrel of an Air-pump is to the capacity of the receiver as a is to b, after every turn the quantity of Air extracted is to the quantity before as a is to $a+b$.

COR.

BAROMETER.

Some time after Torricellius had aſcertained that a column of Mercury thirty inches high was a counterpoiſe to the preſſure of the Atmoſphere, it was aſcertained by Deſcartes, Paſcal and Merſennus, that the Atmoſphere varied in its preſſure.

It was found that the column of Mercury was never leſs than twenty-eight inches, nor higher than thirty-one inches, marking its riſe or fall according to certain atmoſpheric changes, and hence adopted as a weather glaſs.

This variation of three inches appearing too ſmall for minute diviſion, Deſcartes ſuggeſted a method which was executed by Huygens with two tubes, Mercury at the top, and Water at the bottom; as Water is ſo ſenſibly affected by temperature, this form was imperfect.

Cor. 1. , Hence the quantities taken away at any number of ſucceſſive turns form a geometric ſeries, conſequently the whole can never be exhauſted.

In condenſation the ſame ſeries does not take place; after any number of ſucceſſive deſcents, the denſity is increaſed in arithmetic progreſſion.

Caſſini

Caſſini invented an horizontal Barometer; in this Mercury is very apt to be ſpilt.

1668, Dr. Hooke contrived a wheel Barometer; as the Pulley is moved by a ſtring which is influenced by moiſture, this is no ways correct.

The Torricellian will evince an alteration when Dr. Hooke is no ways changed, and when a Verniers ſcale is made uſe of, each inch becomes divided into 100 parts. The ſcale of variation being three inches, and each inch divided into ten parts, on this ſcale is fixed a moveable one of one inch long, and which inch is divided into nine parts; ſo that each diviſion of the moveable ſcale is one tenth of an inch more than the diviſion of the other.

Cauſe of Variation.

Varennius ſuppoſed exhalations differing in denſities. Dr. Halley attributed it to the variable winds. Leibnitz to water in ſtate of rain, not weighing with the Atmoſphere. De Luc attributed it to vapours. Dr. J. Hutton to ſudden changes of heat and cold. Dr. Darwin to ſome decompoſition of the Air. Dr. Bell to Electricity; which laſt ſeem the moſt probable, as the Mercury in the Barometer is higher in the morning

ing and evening than in the middle of the day. So Volta and Reid have obſerved the Atmoſphere is at theſe times more electrical.

The variation in the riſe of Mercury is the greateſt in thoſe latitudes where the greateſt changes in the ſtate of Electricity are alſo.

At St. Helena there is little or no variation; at Jamaica rarely more than $\frac{3}{10}$ of an inch, at Naples one inch, England 2 inches and a half, and Peterſburg 3 inches and one-third.

Height of the Atmoſphere.

If Air were of the ſame denſity at all altitudes, it would be eaſy to calculate the height, as Air is 11900 times heavier than Quickſilver, and 29 inches and a half of Quickſilver being at a mean a balance to the Air; from this the height of the Air would be about 5 miles and a half high. Air diminiſhes in its denſity in the inverſe ratio of the altitudes.

In 1648 Paſcal found the Mercury ſunk 3 inches and one-third upon the Puy de Domme being 3204 feet high. Mr. Caſwell found it ſink 3 inches and $\frac{8}{10}$ on Snowdon-hill, being 3720 feet high.*

SOUND

* Suppoſing the denſity is as the compreſſing force, its denſity at any height is eaſily determinable on the principle

SOUND.

Galilæo, in endeavouring to aſcertain the velocity of Light, diſcovered that of Sound to be near 1100 feet in a ſecond of time; this was more accurately aſcertained by Dr. Halley, Newton, and Dr. Derham, to be 1142 feet in a ſecond: this motion they obſerved to be uniform, whether

of the logarithmic curve. The denſities of the Air will be denoted by the reſpective ordinates drawn perpendicular to the Aſymptot; if any portion of the Aſymptot be a given quantity, there is the ratio of the two ordinates, which intercept that portion, likewiſe given.

If the portions of the Aſymptot are in arithmetic proportion, then the reſpective ordinates are in geometric proportion. Upon this theory it appears that at five miles high, the Air is nearly 2.4 times rarer; at ten miles high, ſix times rarer; at fifty miles high, 6449 times rarer.

It has been obſerved by aſtronomers, by the duration of twilight, and the magnitude of the terreſtrial ſhadow in lunar eclipſes, that the effect of the Atmoſphere to reflect or intercept Light, extends to 50 miles.

Some Meteors have been obſerved very high; one in 1758 aſcertained to be 100 miles high, about a mile and a half in circumference, and exploded with a ſound like diſtant thunder. Either to communicate ſound, or for combuſtion, Air is requiſite; at this height would be infinitely too rare, if the above calculation ſhould be correct.

against

againſt the wind or not. Condamine, at Cayenne, found it to move 1175 feet.

Lord Bacon ſuppoſed Sound to be owing to ſome other principle than Air, as the Sound of a large bell did not in the leaſt agitate a flame placed near it. If a bell be agitated in an exhauſted receiver, no Sound is induced.

Sound is the action and re-action of the conſtituent particles of Air, without any material change of place; while wind is a change of place in a large volume of Air.

A ſhip when in motion does not interrupt any motions within, in whatever directions they are made, ſo the action and re-action of the conſtituent particles of Air are no ways checked by any motion of the maſs of Air where theſe motions are taking place.

The ſame as is produced in the curdly appearance of water in a drinking-glaſs, when rubbing the edge with the finger.

When the action and re-action are propagated through that moving maſs, they neceſſarily are checked in communicating to any maſs of Air from which they are receding; on this account the intenſity of Sound becomes diminiſhed. So on the contrary, in the direction of the wind, Sounds are heard more diſtant.

When a body is ſtruck, it gives forth a certain Sound, not a ſingle and ſolitary one, certain ſecondary and ſubordinate vibrations; if theſe bear no muſical proportion with the primary, a jarring diſſonance muſt be produced.

The art of arranging ſeveral ſounds in ſucceſſion, in a manner agreeable to the ear, is called melody. By pleaſing that organ by the union of ſeveral ſounds heard at one and the ſame time, is called harmony. Diſtance between one ſound and another is called an interval. A chord, compoſed of Sounds whoſe union or coaleſcence pleaſes the ear, is called a conſonance.

Thus the octave of a Sound is the moſt perfect conſonance, then the fifth, afterwards the third.

Diſſonance is a number of Sounds ſimultaneouſly produced, whoſe union is diſpleaſing to the ear; hence in muſical compoſitions, when theſe notes are made uſe of, they are announced to the ear by being found in a preceding chord, and by thus ſeeming to connect the two chords.*

If

* Muſical characters were invented about 670 A. C. by Terpander; till the 13th century the notes were ſquare, on four lines, like thoſe of the Roman church, without any Marks for time: after St. Lewis' reign a fifth line was added. The Egyptians diſtinguiſhed the notes by the ſeven vowels. Voſſius tells us that Pope Gregory firſt made uſe of the firſt ſeven

If we ſuppoſe a ſtring divided into 1000 parts, the different lengths of the ſtring will be as follows:

Ut	C	uniſon,	1000 parts.
Re	D	———	888.9
Mi	E	———	800
Fa	F	———	750
Sol	G	———	666.6
La	A	———	600
Si	B	———	533.3
Ut	C	octave,	500

Why the octave ſhould be moſt in uniſon with the whole chord, then the fifth and third, was firſt

ſeven letters of the alphabet. Guido Aretine, a Benedictine monk, in the 11th century, acquired great fame by expreſſing the muſical notes on a new ſcale, in order to facilitate the learning of this art: he is ſaid to have taken the words from a hymn of Paulus Diaconus, on John the Baptiſt.

Ut quam laxis *Re*ſonare fibris,
*Mi*ra geſtorum *Fa*muli tuorum,
*Sol*ve pollutis *La*biis reatum.

Sancte Johannes.

The ſyllables uſed in ſolmiſation were originally theſe ſix. The Italians finding the ſyllable *Ut* rather difficult to pronounce, rejected it, and made uſe of *Do*, as is obſerved in the Armonia Gregoriana of Gerolamo Cantone; this is now rejected, and the ſolfaing by hexachords, as revived by Pepuſch, is generally adopted.

In the Sound of theſe words there is an evident difference, the intervals between *Ut* and *Re* and *Mi* being equal, are called tones, the others ſemitones.

mechanically explained by Galilæo, by comparing the vibrations of a musical string with those of a pendulum.

A vibrating string is to be considered as two pendulums vibrating in very small arcs, a pendulum is fixed to one point, a musical string to two. A musical string is a double pendulum; hence one half of the chord will vibrate twice, while the whole chord vibrates once.

In every second vibration of the shorter string, there will be a coincidence with the vibration of the longer.

Thus the more frequent the concourse or convibrations are, the greater the consonance. If the length of the longer string be 3, and the shorter 2, their vibrations are as two to three, and called a fifth.

Thus if different pendulums of the following lengths, which are in the same proportion as the subdivision of a monochord, be thrown into motion, those which most frequently coincide in their vibrations produce a visual consonance, and are exactly the same as the notes.*

The

* Supposing a pendulum one yard long; as the lengths of pendulums are as the squares of the times, the following will be the proportionate lengths.

C unison

The agreement between the ſenſations of hearing and ſeeing, is more beautifully illuſtrated by the coincidence between the diviſion of a monochord and the priſmatic colours.*

Sympathetic Sounds.

WHEN one ſtring is ſtrung, another that is in concord with it will anſwer; if a diſcord, no motion will be produced.

This depends on the aerial undulations exciting correſponding vibrations in a ſimilar diſpoſed ſtring.

Hence it is requiſite that the ſtring ſhould be in concord with the other, in order that its vibrations ſhould have their courſe and recourſe ſimilar, conſonant to the aerial undulations.

C	uniſon	39.1 inches.
D	——	31
E	——	27
F	——	21.9
G	——	17.37
A	——	14
B	——	12.3
C	octave	9.7

* Thus B correſponds to red, A to orange, G to yellow, F to green, E to blue, D to indigo, and C to violet.

When not ſo, a recourſe of the ſtring will not correſpond with the recourſe of the aerial undulation, and thus a motion of the ſtring cannot take place.

Echo.

When Sound is reflected by a body on which it infringes, is called an Echo.*

Grounds ſurrounded by a wall, Sound returns to the ear many times, ſometimes ten or twelve. At Simonetto Kircher tells us of one the words were returned forty times.

Not only walls, but even thick woods and rocks, and even clouds. Some naval gentlemen have obſerved that when they enter an harbour with a high circular ſhore, the guns return a ſmarter Sound from the land, than from the ſhip's ſide.

Sometimes a ſecond Echo or a third is more powerful than the firſt, the ſuperior numbers of

* As the ſenſe of hearing in general is not capable of diſtinguiſhing more than 7 or 8 ſyllables in a ſecond, there muſt be the ſpace of $\frac{1142}{8} = 143$ feet between. Thus Woodſtock returns 17 ſyllables; hence 143 multiplied by 17, is 2431 feet.

Sound is reflected in angles equal to the incident ones. On this depends the theory of ſpeaking-trumpets: ſo alſo the whiſpering gallery at St. Paul's.

reflec-

reflections more than compensating for the decay of Sound; thus the celebrated Echo at the Lake of Killarney, in Kerry.

In courts of justice, as in the House of Lords, to prevent any disagreeable reflexions, the walls are adorned with tapestry.

Sense of Hearing.

When the Air is thrown into a tremulous undulation, the Air is acted upon all around; that portion of Air which is contiguous to the external ear, will be reflected by the different depressions there are there, and accumulated in the meatus externus; the aerial tremors strike upon the membrana tympani, which is provided with two muscles, either to relax or to brace up the ear, according to the intensity of the tremors; behind this membrane are placed four small bones, which communicate the impressions to a membrane which covers an opening into the labyrinth. This labyrinth is filled with an aqueous fluid, to which the tremors are imparted; the labyrinth or bony canal, partaking of the motions, communicate the same to the auditory nerve which surrounds the canal externally.*

A canal

* Nerves of the ear in fishes do not appear to pass thro' these so as to get on the inside, as is supposed the case in quadrupeds;

A canal called the euſtachian tube goes from the back part of the membrana tympani into the mouth, to allow of a free ingreſs and egreſs of Air, the ſame as the aperture on the ſide of a drum, elſe the vibrations of the membrana tympani would be impeded.

WINDS.

A Wind is a change of place of a large volume of Air.

Trade Winds.

If the earth were ſtationary, and the Sun always vertical to the Equator, there would only be a North Wind on the North ſide of the Equator, and a South Wind on the South ſide; the Air over the Equator being heated, becomes ſpecifically lighter; the heavier Air preſſing on each ſide, thus conſtitute the Winds.

The Air partakes of the diurnal motion of the Earth, from Weſt to Eaſt, as then the Air is approaching the Equator, it is approaching parallels of latitude which move with greater velocity, and

druped; I ſhould therefore very much ſuſpect that the lining of the tubes in the quadruped is not nerve, but a kind of internal perioſteum.

HUNTER's PHYSIOL. ESSAYS.

hence

hence will have an eaſterly direction. So on the South ſide will be a S. E. wind.*

Theſe Trade-winds extend to about 40 degrees on each ſide of the Equator.

Monſoons.

When from any peculiar ſituation of land in reſpect to ſea, the Tropics become moſt heated, theſe winds are produced ſo that floods of Air ruſh in from the North-Eaſt and South-Weſt; theſe being of different temperature, the Water is precipitated by their mixture. From April to October is a South-Weſt wind, from October to April a North-Eaſt wind.

Theſe Monſoons frequently occur in the Indian Ocean and the Bay of Bengal, and to theſe travellers attribute the riſe of the Nile.†

Eteſian

* The Equator is not the concourſe of theſe Winds, but the northern parallel of 4 degrees, becauſe the Sun is longer on the North ſide of the Equator than on the South ſide. Thus in the Atlantic Ocean the S. E. Trade-wind extends as far as 3 degrees North, and the N. E. Trade-wind ceaſes at 5 degrees North; in this intermediate ſpace are found calms with rain, and irregular uncertain ſqualls; theſe limits varying in ſome reſpects according to the declination of the Sun.

† Theſe Monſoons deluge Nubia and Abyſſinia. The whirling of the aſcending Air was ſeen by Bruce in Abyſſinia;

Etesian Winds

Are Monsoons not having the easterly and westerly directions, being restrained by chains of mountains which confine Egypt.

Cryptæ Æoliæ,

Spiracula or caverns where Wind is evolved. Schenchzer has described many. Sir William Hamilton mentions one in the Italian Isle of Lacco, which acts as an ice-house.

General Winds.

Winds in these latitudes the more regular are the N. E. and S. W. acquiring the easterly and westerly direction from the cause aforementioned; the general winds are not reducible to any known law,

nia: every morning he says a small cloud began to whirl round, and presently after the whole heavens became covered with clouds. By this vortex of ascending Air, the N. E. and S. E. winds flow in to supply the place of the ascending column, became mixed more rapidly, and deposited their rain in greater abundance. Mr. Volney has observed that the rising of the Nile commences about the 19th of June, and that Abyssinia and the adjacent parts of Africa are deluged with rain in May, June, and July.

law, many arifing from local circumftances. Thus the fandy deferts of Africa give a burning heat, whofe effects are felt at Minorca and Gibraltar; from the fame fource originates that fcorching wind which blows at Goree, on the River Senegal; fo the deftructive Wind on the Falkland Iflands.

HYDROSTATICS,

In the original derivation of the word, means the relation between the weight of water and other bodies.

A Fluid may be defined a body whofe conftituent particles are fpherical, and thus eafily yield to any force impreffed upon them. Owing to this property moft of the principles of Hydroftatics depend.

This is the reafon why Fluids prefs equally in every direction, laterally as well as perpendicularly; the preffure is no ways regulated by the quantity of Water, as the perpendicular height and their bafis refpectively.

Thus one pint of Water may be made to prefs with a force equal to one hundred pints.

If a veffel be wider at top than at bottom, the preffure will only be as the width of the lower end multiplied into the height.

Thus

Thus the ſame quantity of Water, however ſmall, may produce a force equal to any aſſignable one, by increaſing the height and baſe upon which it preſſes.

Specific Gravity.

Specific Gravity of a Body is the weight of it, when the bulk is given and compared with another Body of the ſame magnitude; called *ſpecific* becauſe it is the comparative weight of different ſpecies of Bodies; thus a cubic inch of gold is 19 times heavier than a cubic inch of Water, hence it is ſaid to be as 19 to 1.

Rain Water is generally adopted as the criterion, as being eaſily procured and more uniformly the ſame, a cubical foot of which weighs 1000 oz. avoirdupois.

When a Solid is immerſed in a Fluid, it is preſſed by that Fluid on all ſides, and that preſſure increaſes in proportion to the height of the Fluid.

If a heavy Body, as lead, be immerſed in Water to ten or twelve times its own thickneſs below the ſurface of the Water, and the ſuperincumbent preſſure of the Water prevented, the lead will then remain ſuſpended.

If the ſuperincumbent preſſure of the Water be added, then the Body will ſink, only meeting

with

with a refiftance of a weight of Water equal in bulk to the Body immerfed.

By this refiftance a heavy Body lofes fo much of its weight, as equal to its own bulk of the Fluid in which it is immerfed.

This method is of admirable ufe in afcertaining the purity of metals. Fine gold is 19.6 times heavier than Water, while filver is only 11 times heavier; if gold is adulterated with filver, the fpecific gravity of the mixture will be lefs than gold and greater than filver, and thus the proportionate quantity of each may be eafily afcertained.*

* Let the fpecific Gravity of the gold be a, and that of filver b, fince the weight of any Body is compounded of its magnitude and fpecific Gravity; if the bulk of gold in the mixture be x, and that of filver y and c, the fpecific gravity of the mixture, then $ax - cx = cy - by$, and confequently $c - b : a - c :: x : y$.

Thus it will appear that by fubtracting the lofs of gold from that of the compound, the remainder is the ratio of filver; the lofs of the compound from that of the filver is the ratio of the gold.

Suppofing the fpecific Gravity of the compound be 13.11, and the mafs weighs 258.8 grains.

Lofs in Water 258.8 grains of gold is 14.54 grains.
Ditto of filver 24.94
Ditto of the compound 19.74
Then $19.74 - 14.54 = 5.20$ ratio of filver.
And $24.94 - 19.74 = 5.20$ ratio of gold.

In this mixture the quantities are equal.

Thus

Thus Mercury in medicinal as well as philoſophical purpoſes, its purity is a conſiderable object; it is often adulterated with lead, which being ſpecifically lighter, is thus eaſily detected.

HYDROMETER

Is calculated to aſcertain with eaſe and expedition the ſpecific Gravity of Fluids.

Suppoſing an Hydrometer diſplaces a bulk of water equal to 1000 grains, and the ſtem is divided ſo that each diviſion correſponds to a grain of water; if, when placed in rain water it ſinks to the middle of the ſtem, and in common water it is one degree below this, and which will take place if there be the thouſandth part of difference in their ſpecific Gravities.

Proof ſpirits at the temperature of 55 degrees, weigh 7lb. 12 oz. per gallon, and rain water 7lb. 15 oz. ſo proof ſpirits is about $\frac{1}{40}$ part lighter than water.

An Hydrometer of this ſize would require 25 grains more to ſink it in water, than to the ſame height in proof ſpirits.

Theſe Fluids not only vary in their ſpecific Gravities according to the temperature, but the bulk

bulk of the mixture is ſomewhat leſs than the ſum of the two bulks before the mixture.

Sir Charles Blagden has given a table of the real ſpecific Gravities of every 20th addition of Water to Alkohol, from 30 degrees to 100 degrees temperature.*

HYDRAULICS.

PUMPS were in uſe previous to the Chriſtian æra, ſaid to be invented by Cteſebes, an Athenian: the principles on which they acted were not known till the time of Galilæo.

* Monſ. Pouget found Alkohol at 15 deg. temperature to Water as .8199 to 1, he found in ten mixtures in proportions as below, the diminutions of bulk were as follows:

Water.	Spirit of Wine.	Diminution of Bulk.
1 part	9 parts	0.0109
2	8	0.0187
3	7	0.0242
4	6	0.0268
5	5	0.0288
6	4	0.0266
7	3	0.0207
8	2	0.0123
9	1	0.0044

So that the greateſt diminution takes place when the quantities of Water and Spirits are equal.

Thirty-three ſeet of water being a counterpoiſe to the preſſure of the Atmoſphere, whenever a column is exhauſted of Air, the preſſure of the outer Air will force the Water up 33 feet; at any diſtance lower than this, a valve is placed to admit the Water to riſe up and to prevent its return.

The force required to work a Pump, is as the altitude of the Water to be raiſed, and as the ſquare of the diameter in that part where the piſton works.

Forcing Pump.

In this there is no valve in the piſton; after the Water is raiſed into the barrel, it is forced up into a reſervoir. In this the ſtream of Water is alternate; to render it uniform, an air veſſel muſt be made uſe of.

Diving Bells,

As conſtructed by Borellus, Halley, Triedwald, &c. formed like a bell; Dr. Halley in one deſcended 52 feet, and remained an hour and a half. Mr. Smeaton's Diving Cheſt is the beſt conſtructed, and uſed with great ſucceſs at Ramſgate;

Ramsgate; the Air supplied by a forcing Air Pump.*

SYPHON.

FOUNTAIN.

JETS D'EAU.

SPRINGS, RIVERS, &c.

It was imagined generally by ancient and modern philosophers, that Springs originated from Rain and Clouds attracted by the mountains, these formed Springs; Springs, Rivers; and Rivers the Ocean; from these, Clouds were again formed by evaporation. Monf. Gualtieri shewed that the Waters discharged into the Sea by the Rivers of Italy, were to the Rain which fell as 55 to 27; De la Hire, that the Rain of 18 years did not penetrate 8 feet of earth; and Dr. Hales demonstrated that the Rains did not suffice for vegetation.

* In 1774, at Plymouth, Mr. Day engaged for a wager, in a Diving Boat of his own construction, to remain twelve hours, 100 feet deep, perished in the attempt.

In 1783, Mr. Spalding went down with one of his assistants, to view the wreck of the Imperial East Indiaman, at the Kish Bank, Ireland; they remained about an hour, had two barrels of Air sent, on the signals not being repeated, were drawn up and both found dead.

At a certain depth Water is found, theſe effuſions ſeem to be ſupplied from reſervoirs ſtill deeper, they by their turns fed by larger and deeper.

The Earth may be regarded as a Globe having internally a great number of vaſcular ramifications through which Water flows, thrown into motion by the motions of the Earth, and Rivers deſcend in the declivities on the ſurface.

Monſ. Buache conjectures that there is an uninterrupted ſeries of mountains and high grounds, which divide the Earth into four declivities. Theſe chains of mountains forming Belts; thus the Alpine Belt extends through the 45th, 46th, and 47th degrees of N. Lat. paſſing through Switzerland, Tyrol, Savoy, Saltſburg, Auſtria, Moravia, Bohemia, Poland, Pruſſia, &c.

This Belt originally went round the Globe, by extraordinary revolutions has been divided and thus ſeparated the old and new continent, in paſſing under the Sea, the elevated peaks form that Archipelago of Iſlands which derives its name from the unfortunate Bhering, again riſe and enter North America, running in the ſame parallel, and giving riſe to the Ohio, St. Lawrence, Miſiſſipi, till they are loſt in Canada.

Thus Mungo Parke obſerved a ſimilar Belt in Africa, between 10 and 11 degrees North, and 2

and

and 10 degrees Weſt Long. from Greenwich, in the higheſt part of which chain was ſituated the ſource of the Gambia.

Owing to theſe irregularities of the ſurface of the Earth, Currents and Streams proportionably take place: thus the greateſt depth of the Wells at Schemnitz is 200 fathoms, yet it appears from the barometrical calculation of Noda, that the greateſt depth of theſe mines is 286 fathoms higher than the city of Vienna.

In digging into the Earth, according as the ſurface is more or leſs elevated, theſe veſſels are more or leſs deep, when one is cut into, conſtitutes what is called a Spring.

Sometimes this opening may be in the loweſt part of the veſſel, the Water being prevented finding its own level, in conſequence of the reſiſtance of the ſuperincumbent Earth; when this is removed, riſes conſiderably up: thus the Well at Sheerneſs the Water roſe 300 feet above its ſurface. At Connecticut, in America, a Well was dug 70 feet before Water was found; on removing a large ſtone, the then uncontrouled Spring guſhed forwards, run over, and ever ſince has formed a Brook.

Upon theſe principles may be eaſily explained why a warm mineral Spring may be contiguous to a common one.

Under Currents.

If one of these aqueous vessels should open in a River, in a direction opposite to the stream, it will constitute an Under Current.

Dr. Halley observed this in the Straits of Gibraltar; Triedwald has particularized the same in the Baltic, and Smeaton the same at Long Reach.

In the Current of the Baltic a vessel is carried with great rapidity; to check this, a flat board is sunk about 30 fathoms, the contrary direction of the Under Current stops their progress.

HYGROMETER

Is an instrument intended to discover the moisture contained in the Atmosphere.

All substances which are twisted are contracted by moisture, while other substances are lengthened. Thus wood expands by moisture; ropes, catgut, beard of a wild oat, &c, contract. Mr. De Luc found that whalebone and box cut across their fibres increased nearly in proportion to the quantity of moisture; whalebone he preferred, as it uniformly returned to the same point, and its expansion greater, nearly one eighth of its length.

THERMOMETERS.

An inſtrument contrived for meaſuring the relative degrees of heat in Bodies.

Its invention is attributed to ſeveral perſons, Sanctorio, Galilæo, Father Paul, &c. Drebbel introduced it into England.

The firſt were only filled with Air, about 2 feet long, and a ſmall quantity of coloured liquor in the tube. Air, although very ſenſible, yet being influenced by other cauſes than by temperature, on this account is imperfect. The Florentine academicians filled them with Spirits. Dr. Hooke introduced them into England. As ſpirits of wine will not aſcertain the higher degrees of Heat, Newton adopted linſeed oil in a tube 3 feet long, and half an inch wide, and the ball two inches; this being inconvenient from its length, and inaccurate from the oil adhering to the ſides of the tube, induced Farenheit to fill his with Mercury, and which at the ſame time was alſo done by Prims in England. When Maupertuis and the French philoſophers went to the polar region, the Spirit Thermometers burſt, the mercurial ones remained perfect; at the ſame time Boerhaave adopting Farenheit's, render it general.

All Fluids, excepting Air, are inferior to Mercury in ſenſibility.

Graduation of the Thermometer.

At first there were no general ſtandard; the Florentines adjuſted to the greateſt ſunſhine Heats of their country, which were neceſſarily vague and uncertain. Mr. Boyle recommended the freezing of the eſſential Oil of Aniſeed, or the congelation of diſtilled Water. Dr. Halley preferred taking as a ſtandard places deep under ground, as Mr. Boyle had obſerved that 130 feet deep the Thermometer was uniformly the ſame: De la Hire and Miraldi found the ſame under the Royal Obſervatory at Paris, and thus graduated theirs. Afterwards Dr. Halley recommended the heat of boiling water, which Newton and Amontons adopted; Farenheit firſt obſerved that this varies as the preſſure of the Atmoſphere, hence Thermometers ſhould be graduated when the Barometer is at 29 and $\frac{1}{2}$. Mr. Cavendiſh, obſerving a librating motion in the boiling heat, recommends the ſteam as more correct.

The Graduation which is made uſe of in England and Holland, is that of Farenheit's; in the forming of which he made uſe of a large Thermometer, ſuppoſing the greateſt poſſible degree of cold was that produced by a mixture of Snow or beaten Ice and Sal Ammoniac, he fixed this point at Zero, the Mercury in the tube weighed 11124 grains;

grains; when placed in water beginning to freeze, the Mercury roſe up 32 grains, which he marked as his freezing point; when placed in boiling water, it roſe up 212 grains, and which characteriſed that degree.

To have a very ſenſible Thermometer, the bore ſhould be very ſmall, and the ball large, if inſtead of being round was flat, the Mercury would expoſe a larger ſurface.

To aſcertain the higher degrees of Heat, Mr. Wedgewood's ſquare pieces of clay, which contract, by great intenſities of Heat.*

Degrees of Cold.

BOERHAAVE imagined that the Air was never colder than 32 degrees; and when Farenheit had by

* Mr. Wedgewood divides his ſcale into 160 degrees, the firſt degree that at which clay firſt begins to contract, the loweſt degree of his Thermometer equal to 1077 of Farenheit; he found the following to be melted at the degrees here marked.

Nankeen Porcelain....21877 Degrees Farenheit.
Pig Iron for caſting...20577
Plate Glaſs............17197
Welding Heat of Iron.13427
Gold melts............5237
Silver melts...........4717
Braſs melts............3807

by a mixture of pounded Ice and Aqua Fortis produced a degree of cold of 72 degrees below the freezing point; a cold ſays Boerhaave that muſt prove deſtructive to all animated nature.

At Peterſburg, in the year 1759, the Thermometer was 74 degrees below the freezing point. Pallas obſerved at 120 deg. when Gmelinus publiſhed an obſervation of its ſinking to 137, it was doubled in 1760: the ſame was obſerved in Sweden.

Artificial Cold.

PROFESSOR Braun, in December 1759, reſpecting Farenheit's experiments for want of Ice and Snow, and to his great ſurpriſe ſunk down to 184 degrees below freezing, and the Quickſilver rendered ſolid. In 1763 Pallas had $\frac{1}{4}$ lb. of Quickſilver froze by the natural Cold.

The Southern Latitudes are much colder than the Northern, which ſeem to ariſe from the different diſtances of the Earth in the Winter and Summer, as the Earth is three millions of miles nearer the Sun in our Winter than in our Summer; although the rays of Light are more oblique, yet we are one thirty-ſecondth part nearer the Sun. In the Southern Latitudes it is the reverſe: in their Winter the Earth is alſo three millions of miles more remote; ſo that they have an increaſed diſtance added to the obliquity of the Solar rays.

ASTRO-

ASTRONOMY.

That branch of natural knowledge which relates to appearances in the Heavens and the causes of them, is termed Astronomy.

A spectator viewing the Heavens, conceives himself situated in the centre of a Sphere, upon the concave surface of which, all the heavenly Bodies are disposed.

The system at present adopted is that of the most ancient; Pythagoras derived it from his intercourse with the Chaldeans, and this continued till the period of Ptolemy, who lived about a century after our Saviour.

The Ptolemaic theory prevailed till the 15th century, when Copernicus revived the Pythagorean System.

About 50 years after another system arose, created by Tycho Brahe, which has been adopted by very few.

The Pythagorean or Copernican System.

The Sun in the centre, round which all the planetary Bodies revolve, and in the following order; Mercury, Venus, the Earth and Moon revolving round the Earth, Mars, Jupiter, Saturn, and Georgium Sidus.

This

This order coincides with the different appearances.*

Ptolemaic Syſtem

Supposes the Earth in the centre, the Moon, Mercury, Venus, Sun, Mars, Jupiter and Saturn moving round.

Syſtem of Tycho Brahe.

The Earth in the centre, the Sun and Planets revolving round once in 24 hours.

Orbits of the Planets.

Till the period of Kepler, 1609, the Orbits of the heavenly Bodies were believed to be circular; he firſt publiſhed his Commentary on the Motion of Mars, and ſhewed that the Planet deſcribed an Ellipſis about the Sun, and that the Sun was placed

* Venus and Mercury ſometimes appear ſtationary, at other times retrograde in their motions, while if the Earth were in the centre, they ought to be obſerved uniformly moving round: alſo Venus and Mars appear ſix or ſeven times larger at one time than at another, which demonſtrate that in their orbitary revolutions there muſt be very great difference in their diſtances from the Earth.

in

in the lowermost focus; he conjectured this might be the case with every other.*

Sun†

In diameter is 893522 miles, and is 1434400 times greater than the Earth. The Sun has two motions, one round its Axis in 25 days six hours, and an irregular orbitary one round the common Centre of Gravity. As the Centre of Gravity can never be farther removed from the Sun's Centre than its circumference, the orbitary revolution is comparatively so trivial, that the Centre of the Sun is generally calculated as the Centre of Gravity of the solar system.

* Kepler whimsically imagined that the Sun was alive, and that the revolution round its Axis was the action of its Soul; the eccentricity of the Orbits of the Planets, he imagined the Bodies of the Planets were composed of fibres in form of bearded arrows, which lay all the same way, flattened when their points were offered to the Sun on one side, which stood erected when offered to it on the other; so that when that side was exposed to the Sun where these barbs retreated and flattened, this mark of respect was deemed friendly: hence the Sun attracted it nearer to itself, when they were reverse and in an offensive, hostile motion, was supposed inimical and repelled by the Sun.

† Called Sol by the ancients, because as Macrobius says, he appears *solus* or alone.

When

When the phafe of the Sun is examined through a telefcope, a number of fpots is obferved of various fizes; by daily obfervation thefe gradually change their apparent fituation, and return again into their fame place at the expiration of 25 days, fix hours: owing to this the revolution round its Axis is afcertained.

Thefe fpots are fome of them of an amazing fize, equal in magnitude to the furface of the Earth. Rev. Mr. Wollafton of Cambridge fays, with a twelve inch reflector he faw a fpot burft to pieces, and appeared like a piece of ice broke, radiating in various directions.

What thefe fpots are, is a fubject much difputed. Scheiner thinks they are volcanoes not appearing fo luminous as the Sun, have that dark look: hence he calls them Faculæ or little Torches. Dr. Wilfon fancies they are excavations in the Sun, as he fuppofes the Sun is in a ftate of combuftion on its furface: fome of them are found to be 4000 miles wide, and as many deep; thefe are obferved to vary in their fize, and fometimes entirely vanifh, while new ones are produced. Hevelius obferved one which appeared and vanifhed in 16 or 17 hours, and none of them have been obferved to continue longer unchanged than 70 days.

As

As it is now generally believed that the Sun is the fountain of Light, but not of Heat, Dr. Herſchel thinks it may be inhabited.

Mercury

In diameter is 3261 miles, 37 millions of miles diſtant from the Sun, and about $\frac{1}{14}$ as large as our Earth; he moves round the Sun in 88 days, a velocity equal to 110680 miles every hour.

Mercury, like all other Planets deriving all its Light from the Sun, will be ſeen by the inhabitants of the Earth undergoing all the changes of the Moon; this was firſt obſerved by Galilæo, who firſt applied a teleſcope to the Heavens.

Mercury never appearing remote from the Sun, it is but rarely he can be ſeen; in general he appears within a quarter of an hour of the Sun, ſo immerged in its luminous rays, that no obſervations have been made on its Body, in order to aſcertain its revolutions round its Axis.

Venus.

In diameter is 7699 miles, and 69 millions of miles diſtant from the Sun, revolves round this luminary in 224 days, and round its Axis in 23 hours, 22 minutes, in ſize is equal to our Earth; its

its orbitary velocity is 80955 miles per hour. Venus being more remote from the Sun, is more easily examined.

Galilæo first observed that when she was perfectly round and full she appeared small, and larger as she became gibbous.*

Cassini, in 1666, first observed a bright spot in Venus, and concluded that she revolved round her Axis in little less than one of our days.

In 1726, Signior Blanchini observed many spots in Venus.

Mr. Schroeter, of Bremen, thinks Venus has an Atmosphere; when observing Venus in her Crescent, the outer Limb is more luminous than the inner ragged one, the Light fading away, as is observed in the gradual diminution of Light on Atmosphere; this must be more sensible in the middle than at the Cusps.

* The lustre of Venus being sometimes so great as to be seen in the day-time, gave occasion to Dr. Halley to enquire into the cause: he proposes this problem, " In which part of her Orbit, with respect to the Earth, is the illuminated portion of Venus' Disk, turned towards the Earth, the greatest that it can be"?

He found this to be when that Planet is about 40 deg. distant from the Sun,* and when little more than one quarter of her visible Disk is luminous, and she resembles the Moon about five days old, in every eight years she returns to the like position again; so that she may be seen the same day of the month, and hours, nearly in the same place.

When

When Venus departs out of the Sun's Rays, on the weſtern ſide, we ſee her in the morning juſt before day-break, ſhe is then called the Morning Star, at this time appears like a fine thin creſcent: juſt a verge of ſilver light is ſeen on her edge.

Of the ſuperior Planets.

Mercury and Venus are termed the inferior Planets, thoſe which move in Orbits circumſcribing that of the Earth, are termed ſuperior. Theſe exhibit phenomena conſiderably different, in their motions they always appear retrograde when in oppoſition, and direct when in conjunction.

The elongation of the inferior Planets is leſs than 90 degrees, ſo ſeem conſtantly to attend the Sun, the ſuperior are ſometimes 180 degrees.

The ſuperior Planets are never ſeen croſſing the Sun's Diſk, as in their revolutions they are ſometimes nearer to, and ſometimes further from the Earth, and their apparent diameter is found to vary according to the difference in their diſtance.

Mars

Is 5312 miles in diameter, 146 millions of miles from the Sun, goes round the Sun in 686

days, revolves round its Axis in 24 hours, 39 minutes, is $\frac{3}{16}$ of the ſize of the Earth, and moves in its orbit with a velocity of 55783 miles in an hour.

Dr. Hooke firſt obſerved a ſpot in Mars, by which its revolution round its Axis was aſcertained by Caſſini. In 1704 Maraldi obſerved many ſpots.

Mars, when in oppoſition to the Sun, is five times nearer to us than when in conjunction.*

Mars appears to have a conſiderable Atmoſphere. Caſſini obſerved a Star in the water of Aquarius, at a diſtance from the Diſk of Mars became ſo faint before its occultation, that it could not be ſeen with the naked Eye: Roemer obſerved the ſame at Paris. Alſo Dr. Herſchel has often perceived occaſional changes of partial bright Belts, which ſeem to ariſe from the variable diſpoſition of an Atmoſphere.

Jupiter

Is 90,255 miles in diameter, 499 millions of miles from the Sun, revolves once round the Sun

* As the Earth is at a mean 96 millions of miles from the Sun, then Mars at its neareſt diſtance will be 50 millions of miles from the Earth; when at its greateſt diſtance, will then be 242 millions of miles.

in 11 years and 314 days, and round its Axis in 9 hours 56 minutes; in magnitude is 1479 greater than the Earth, and moves in its orbit with a velocity of 30,193 miles in an hour.*

This Planet appears with Bands or Belts, which were firſt obſerved by Gaſſendus; Caſſini, while viewing Jupiter, ſaw five Belts, and in the courſe of an hour two diſappeared. What theſe are, and why when obſerved always form parallel ſtrata, are circumſtances not yet accounted for.

Saturn

Is 80012 miles in diameter, 916 millions of miles diſtant from the Sun, revolves round the Sun in 29 years 167 days, and round its Axis in 10 hours 12 minutes; its magnitude is 1030 greater than the Earth, and moves in its orbit with a velocity of 22,298 miles per hour.

Galilæo thought it a tricorporate Body,† ſuppoſing it to be compoſed of three globes; 50 years afterwards Huygens aſcertained its annular ſtate. What Galilæo took for two Stars, were parts of a Ring, which ſingular and curious appendage encompaſſes the Body of this Planet without touch-

* This great velocity of Jupiter renders his figure ſpheroidal; his equatorial diameter to the Polar one is as 13 to 12.

† Altiſſimam planetam tergeſimam obſervavi.

ing it; the ſpace between the Ring and Globe is about 21,000 miles, and the breadth of the Ring is nearly the ſame. Dr. Herſchel has diſcovered another Ring, concentric to this, and much larger.

What theſe Rings are intended for is not known; they are inclined to the plane of the ecliptic in an angle of about 30 degrees, hence well calculated to reflect Light to the polar regions of Saturn.

Georgium Sidus

WAS not known as a Planet till Dr. Herſchel's obſervations were engaged to it from the ſteadineſs of its Light; in applying higher magnifying powers to his teleſcope he found the diameter increaſed; in two days its place in the Heavens was changed: to ſee it thus, the magniſying power ought to be more than 300 times.

This was diſcovered in 1781; in diameter is 34,217 miles, diſtant from the Sun 1832 millions of miles, performs its revolution in 80 years; in magnitude is 81 $\frac{1}{16}$ larger than the Earth, and moves with a velocity of 16,411 miles per hour.

The mean diſtance of all the Planets is generally more conciſely expreſſed by aſtronomers; ſuppoſing the diſtance of the Earth from the Sun be

be divided into ten parts, Mercury may then be eſtimated at 4, Venus at 7, Mars at 15, Jupiter 52, Saturn 95, and the Georgium Sidus 190 parts.

Earth

Is ſituated in the Solar ſyſtem, between Venus and Mars; its mean diſtance from the Sun is 96 millions of miles, its diameter 7920 miles; moves round the Sun once in 365 days, 5 hours, 48 minutes, and with a velocity in its Orbit of 68,856 miles per hour.

Who it was found out the Earth's ſpherical figure, lies hid in the dark ruins of antiquity; certainly the opinion is very ancient, for when Babylon was taken by Alexander, Eclipſes were there found calculated.* Thales in the Ionic ſchool

* When any Body in all ſituations and under all circumſtances projects a circular ſhadow, that Body muſt be a Globe. Thus the ſhadow of the Earth, whether projected Eaſt or Weſt, North or South, in eclipſing the Moon, is always circular.

The Earth loſes very little of its ſphericity by mountains and valleys. Mont Blanc, an enormous maſs of granite in the centre of the Alps, meaſures 2750 fathoms; the Cordilliers 3030 fathoms, Quito 1707, El Coraſin 2470, Ek Atlas 2730, all parts of the Cordilliers or Andes. Peak of Teneriffe 1934 fathoms, Mount Ætna 1672, Mounts Olympus, Taurus, and Cenis 1460 fathoms, &c.

collected all the relations given by travellers, brought all these particular Lights upon a sphere, and produced in Greece the first terrestrial Globe.

Secondary Planets

Are those which attend the primary Planets; Mercury and Venus have none, the Earth is attended by one Moon or Satellite, which is situated about 240,000 miles from the Earth, and moves round the Earth in 27 days, 7 hours, 43 minutes, which is called the periodic month; in this time she has performed one entire revolution about the Earth, from any point in the Zodiac to the same again.

The Moon's motion considered with relation to the Sun, is the excess of the velocity of the Moon's motion above the velocity of the Sun's apparent motion; this excess varies: the mean motion of the Moon from the Sun is 12 degrees, 11 minutes, 26 seconds in a day, which carries the Moon from one conjunction to another in 29 days, 12 hours, 44 minutes, 3 seconds. This is called a synodical month or lunation.

The Moon turns about its own Axis in the same time it moves round the Earth; it is on this account that she always presents nearly the same face to us: by this motion round her Axis she turns

turns juſt ſo much of her ſurface conſtantly towards us, as by her motion about the Earth would be turned from us.*

The Moon, when viewed through a teleſcope, does not appear ſmooth like a ſpeculum, rough and uneven with mountains, caverns and valleys. Theſe irregularities are more particularly obſerved in the creſcent ſtate.

Whether there is any Atmoſphere about the Moon, is not yet known, ſhe always appears clear when our Atmoſphere is; yet Feuillée and De la Hire ſays, that a Star paſſing behind the Moon has been refracted; this by others is denied, yet ſome have obſerved the Sun to have a trembling kind of motion juſt before an Eclipſe, and to appear oval.

In 1787 Dr. Herſchel obſerved ſome luminous ſpots in the dark part of the Moon, occaſionally very vivid; he deems them volcanoes. Don Ulloa, when in South America, had obſerved a ſimilar ſpot at the time of an Eclipſe; he thought there was a hole through the Moon, which let the Light paſs through.

* The motion about the Axis is equable and uniform, but that about the Earth is irregular, from the Orbit being elliptical, conſequently the ſame preciſe part is not actually preſented towards the Earth; a little ſegment on the Eaſtern and Weſtern Limb appear and diſappear. This is called the Moon's *Libration*.

Different Phaſes of the Moon.

As the Moon goes round the Earth, more or leſs of her enlightened half will be preſented towards us, ſometimes ſhe looks full upon us, ſometimes only half her enlightened face; ſoon ſhe appears as a radiant Creſcent, and at another time inviſible.

Moon revolves round the Earth from Weſt to Eaſt, when in oppoſition to the Sun we ſee it quite full, when in conjunction is generally inviſible a day or two; then a line appears in a creſcent form, increaſing, till at the firſt quarter ſhe appears in the form of a ſemicircle.

The next Planet which has Moons is Jupiter, he has four of them; theſe were diſcovered by Galilæo, who called them the Medicæan Stars; of theſe he only ſaw three, the fourth was diſcovered by Huygens.

The application to navigation was ſuggeſted by Galilæo, and firſt put into practice by the aſtronomers Condamine, Bougouer, Don Ulloa, &c. By theſe Roemer determined the velocity of Light.

Satellites of Saturn.

Huygens difcovered the fourth Satellite: Caffini 16 years after difcovered four, being the 3d, 5th, 6th and 7th. In 1789, Dr. Herfchel difcovered two nearer the Body of Saturn, viz. the 1ft and 2d. Thefe are fo minute as not to be feen unlefs the Air is exceeding clear.

Satellites of Georgium Sidus.

In 1787, January 11, Dr. Herfchel difcovered two Moons, &c.

All thefe Moons appear to anfwer the important purpofe of reflecting Light to their refpective primaries, and if they refemble ours; this feems to be the principal purpofe of their creation, they feem not to be calculated for Beings like unto ourfelves.

Seafons.

The Orbit of the Earth being elliptical, and the Earth's Axis being inclined to the plane of this Orbit, in an angle of 23 degrees, 30 minutes, to thefe the change of Seafons is owing.

As

As far as this angle extends, the inhabitants of every part of this circle will successively have the Sun vertical to them.

The Summer is nearly eight days longer than the Winter; as the Earth is farther removed from the Sun in Summer than in Winter, the velocity with which it moves through the Orbit is diminished: the Earth as well as all the Planets, describes equal areas in equal times.

Division of Time.

THERE is no correct account respecting the ancient division of Time; it is said by some the Egyptian years were our months: the Arcadians divided their year into three months, the Romans into ten.*

The

* Romulus made this division, viz. March, April, May, June, Quintilis, Sextilis, September, October, November, and December; Quintilis and Sextilis were afterwards changed into July and August, in honour of the two Cæsars. Numa added January and February. Even this increase divided the year into only 354 days, the eleven days he doubled every second year and made another month, called Mercidonius: this intercalation was left to the priests, who frequently omitted it; thus the feasts fell on different times. Julius Cæsar to rectify this, made one year of 15 months, he then added the 11 days to the 354, making the year 365 days, equal to the

The Time meaſured by the Sun's apparent revolution from any fixed ſtar to the ſame fixed ſtar again, is 365 days, 6 hours, 9 ſeconds, 14 thirds.

The Time meaſured by the Sun's revolution in the Ecliptic, from any Equinox or Solſtice to the ſame again, is 365 days, 5 hours, 48 ſeconds.

the courſe of the Sun within 6 hours; theſe hours were left alone till they made one day; every 4th year he placed this day, and in that part of the calendar where the intercalary month uſed to be put, viz. five days before the end of February, and ſixth of the Calends of March, for this year the ſupernumerary day was called Biſſextus; this is called the Julian Period, and which would have been correct, had the Sun apparently finiſhed its revolution in 365 days, 6 hours. The interval of Time from the Sun's leaving the firſt point of Aries, till his return to it, is 365 days, 5 hours, 48 minutes, and 48 ſeconds, being 11 minutes and 12 ſeconds leſs than the Julian computation: this in a century makes a difference of 18 hours, 24 ſeconds. At the time of the Council of Nice, in 1582, it was found that the Sun had entered the equinoctial circle on the 11th of March inſtead of the 21ſt. Pope Gregory XIII. took theſe 10 days, ordered that the 11th ſhould be deemed the 21ſt. This was called New Stile, and immediately adopted in every Roman Catholic country, not adopted in England till the middle of this century: to prevent this difference, he ordered that every 100th year ſhould be a common year, not a Leap Year. This will lead into an error on the contrary ſide; every century the difference does not amount to one day, to render it more equal every 400th year ſhould be Leap Year.

The

The former is called the Sidereal Year, the latter the Tropical.

The Lunar Year, or twelve Synodical Months, consist of 354 days, 8 hours, 48 seconds, and which seems to have been the year the Romans at first adopted.

A Week.

The first mention of a Week is in Genesis, derived from the Mosaic account of the Creation. Josephus observes that in all cities of Greeks or Barbarians, the seventh day is observed. Dion Cassius, the historian who wrote in A. D. 210, says, the referring of days to the seven Planets was an invention of the Egyptians, in the order of the vulgar system, viz. of Ptolemy's. Supposing the Earth in the centre, Saturn to govern the first hour of Saturday, counting according to the order of the Planets, the twenty-fourth hour will fall to Mars, the first hour of the next day will belong to the Sun, who therefore will govern that hour, and give the name to the day, &c.

Eclipses of the Sun and Moon.

As all the Planets derive their Light from the Sun, whenever one Planet is interposed between the

the Sun and another Planet, a proportionate deprivation of Light will take place.

If the orbit of the Moon had not been inclined to the plane of the Ecliptic, there would then have been two Eclipſes every lunation; as the Orbit is inclined in an angle of 5 degrees, there can only be an Eclipſe when the Sun, Moon, and Earth are in a right line. The Moon's Orbit, if produced, would cut the Ecliptic in two points, called her Nodes, or places of interſection, ſo that one half of the Moon's Orbit will be above the Ecliptic, the other below.

As an Eclipſe of the Sun can only take place at New Moon, if the Moon in the courſe of her revolution ſhould be at this period in the ſuperior part of her Orbit, her ſhadow when projected will paſs above the Earth, and hence no Eclipſe: if at this period ſhe ſhould be at or near the Node, ſhe will then be nearly in a right line, and her ſhadow will fall on the Earth.

There are more Eclipſes of the Sun than of the Moon, but more Eclipſes of the Moon viſible than of the Sun.

If the Moon's Nodes had no retrograde motion, there would be juſt half a year between the time of the Sun's conjuctions with the Nodes; the Eclipſes fall ſooner every ſucceeding year, as to prove that the Nodes move backwards 19 $\frac{1}{2}$ degrees

every

every year, hence go backward through all the ſigns in 18 years and 11 days. This was firſt aſcertained by Pliny, hence called

Plinian Period.

If to the mean time of any Eclipſe, either of the Sun or Moon, there are added 18 years, 11 days, 7 hours, 43 minutes and a half, will aſcertain the mean time of the return of that Eclipſe. As the Nodes go backwards 19 degrees, nearly equal to 19 days of the Sun's motion; hence taking half of this from 182 days and a half, or half a year, will remain 173 days for the time of the Sun's being in conjunction with the other Node.

Tranſits.

Mercury and Venus occaſionally paſs over the Sun's Diſk.

Mercury's Orbit is inclined 7 degrees to the Ecliptic, and his Nodes is in the 14th degree of Taurus, and 14th degree of Scorpion. The Earth is on theſe points on the 5th of November and the 4th of May, if Mercury is then near the Nodes, at theſe times there will be a Tranſit, appearing like a dark round ſpot upon the Diſk of the

the Sun. This takes place about once in three years, not always viſible to us.

Venus' Orbit is inclined 3 degrees and a half croſſing the Ecliptic in the 14th degree of Gemini and Sagittarius; as this Orbit is ſo large, it rarely happens that the Earth is in a right line with Venus and the Sun, when Venus is in her Nodes.

Dr. Halley having propoſed a method of determining the diſtance of the Sun from the Earth, by the paſſage of Venus over the Sun, to one-fortieth part of a ſecond. With this view ſome aſtronomers were ſent with Captain Cook in 1761 to St. Helena. There will not be another viſible one till 1996.

Tides.

THE ancients had very imperfect ideas of Tides. Homer ſpeaking of Charybdis, ſays,

"*Thrice* each day it riſes."

There is little or no Tide in the Mediterranean, Charybdis is only a whirlpool in the Streights of Sicily. Herodotus, ſpeaking of the Red Sea, ſays there is a flux and reflux of water in it every day.

Horace ſpeaks of Tides as a phænomenon he had either ſeen or heard of,

"Quæ Mare compeſcant cauſæ."

There are a few places in the Mediterranean in

which Tides have been obferved, viz. the Syrtic, the Adriatic, the Faro of Meffino, and the Euripus: the Faro and Euripus being narrow channels, are more currents; in the other two places Dr. Shaw particularizes Tides.*

Pytheas, of Marfeilles, who lived about the time of Alexander the Great, firft fuggefted that Tides were governed by the Moon; Kepler was the firft who attributed them to a principle of Gravitation.

Galilæo imagined Tides to be produced by the different velocities of the annual and diurnal motion of the Earth; which explanation would anfwer well, if the Tides occurred at noon and at midnight, and no variation in their rife; but they are found to move through the 24 hours, and vary daily in their rife.

Dr. Wallis, in 1666, furmifed that the Earth and Moon having a motion round their centre of Gravity, according as the acceleration and retardation were coincident.

Sir Ifaac Newton, more partial to his fyftem of Gravitation, by a very laboured hypothefis of the attractive powers of the Sun and Moon, endeavours to explain the phænomena of the Tides.

* Varennius tells us of one philofopher who imagined the Earth and Sea to be a living creature, and the Tides caufed by its refpiration; fome imagined they proceeded from a great whirlpool in Norway, which for fix hours abforbs the water, and afterwards difgorges it, &c.

Suppofing

Suppofing a power of attraction to exift in all the fpace between our Earth and the Sun and Moon, is attended with many difficulties: the following theory is offered.

The mean velocity of the Moon round the Sun is the fame as the Earth; fuppofing the Moon of the fame denfity as the Earth, its proportionate quantity of matter to the Earth will be as 1 to 49.22*. As the mean diftance of the Moon from the Earth is 240,000 miles, the common centre of Gravity of thefe two Bodies will be inverfely as their weights from their refpective centres, viz. 4896 miles from the centre of the Earth, 936 miles above the furface.

When on Gravitation it was obferved, that this principle appeared probable to be that general impulfe which this Earth and all matter appertaining to it; has in confequence of its orbitary revolution, that the diminution of Gravitation towards the equatorial parts correfponded to the counteractive, the annual motion of the Earth by the diurnal one.

* As fpheres being to each other as the cubes of their diameters; the Moon being 2161 miles in diameter, and whofe cube is 10091699281; the Earth being 7920 miles in diameter, whofe cube is 496792188000; thefe are to each other as 1 : 49.22. The greateft diftance of the Moon from the Earth is 256,785 miles, and its leaft diftance 223,211; therefore its mean diftance is 240,000 miles,

A third motion of the Earth, round the common centre of Gravity of the Moon and Earth, will act with a power proportionate to the difference of this motion with the annual one.

When the Moon is in her quadratures, the centre of Gravity will lie very near the Line of the Earth's Orbit; the deviation from its annual motion is considerably less, the centrifugal power is proportionably so, and the Tides at this period are the least. When the Moon approaches the right Line between the Sun and Earth, which Line being perpendicular to the Earth's Orbit, the common centre of Gravity of the Moon and Earth will also be perpendicular to the Earth's Orbit; the centrifugal power will be the greatest, and the Tides will be Spring Tides or the greatest.

The Tides are observed to be the greatest at the time of the vernal and autumnal equinoxes, at a time when the revolution of the Earth round its Axis adds its greatest centrifugal power to the motion round the centre of the Gravity.

When the Moon is in the Northern Signs at the Equinoxes, then the Tides in our Latitudes are the greatest; so with the other side of the Line, when the Moon is in the Southern Signs.

Thus it is observed that the Tides in the Torrid Zone are the most violent, they diminish in their force as they approach the Pole. In several parts

of

of the Northern Ocean are very ſmall; in the Baltic Sea, in Hudſon's Bay, little or none; while the Tides are very high in the Bay of Sunda, Malacca, Coaſt of China, Japan, Panama, Bay of Bengal, &c.

When the Earth is at the Solſtices, viz. about the 21ſt of June and the 24th of December, the Tides are the leaſt, inſtead of the motions of the Earth coinciding with the motion round the centre of Gravity, here are the moſt oblique, therefore the centrifugal power is the leaſt.

As the motion of the Moon is from Eaſt to Weſt, Waters which flow in this direction will have the greateſt Tides; if they flow from Weſt to Eaſt, the oppoſite motion is proportionably counteracted, as in the Mediterranean the Sea flows from Weſt to Eaſt, hence little or no Tide.

The Moon in her Apogæum is near 24000 miles more remote from the Earth than at another, hence the common centre of Gravity becomes two or three hundred miles more removed from the Earth, and when this coincides with the New and Full Moon, will make a variation in the Tides.

So alſo the Earth in different parts of her Orbit has different degrees of velocity, which alſo require to be taken into conſideration.*

Fixed

* When the Moon is in the Syzygia, i. e. the Line which joins the centres of the Earth and Sun, ſhe has a ſwifter

 motion

Fixed Stars.

The fixed Stars are diſtinguiſhed from the Planets by their never changing their relative ſituation, and *their ſcintillation**. To diſtinguiſh the Stars with regard to their ſituation, the ancients divided them into Conſtellations, digeſting them into the forms of ſuch animals, &c. which are delineated upon the Celeſtial Globe.

As the ancients had obſerved that the Planets moved in Orbits which formed ſmall angles with

motion round the Earth; but in the Quadratures ſhe goes ſlower. The Moon, like all the other Planets, moves in Ellipſe, one of whoſe centres is the Earth, as ſhe deſcribes Areas proportional to the times, the motion of the Moon muſt be quickeſt in Perigeon, and ſloweſt in Apogeon.

The limits of an Analyſis will not allow to explain all theſe circumſtances, ſo far as they influence the Tides, which ſoon will be more largely treated of in a Work nearly arranged for the Preſs.

* Scintillation of the Stars is moſt in thoſe Stars which are neareſt the Horizon, ſeems to be produced by the intercepting particles of duſt floating in the Air. If a ſmall flat piece of glaſs, about the ſize of a ſilver penny, be laid upon the ground, between the obſerver and the Sun, with the plane of it a little declining from the Sun; when about 30 or 40 yards from it, the image of the Sun reflected from it appears bright and ſteady; when 3 or 400 yards, will twinkle in the ſame manner as the Stars do.

the

the Ecliptic, one half of their courſe on the North ſide, the other half on the South ſide, never exceeding 8 degrees from it; theſe were diſtinguiſhed by two leſſer circles parallel to the Ecliptic, one on each ſide; dividing this ſpace into Conſtellations, repreſented by animals, was called Zodiac, or Circle of Animals.*

Number

* Zodiac. Macrobius firſt explained the reaſon of the Conſtellations; Cancer and Capricorn, thus being called, the one emblematical of the retrograde motion of the Crab, the other ſimilar to the aſcending of Goats in their feeding; Aries, Taurus, and Gemini, the chief attention of the Eaſtern nations were to their Flocks. Gemini, which now is repreſented as Caſtor and Pollux, in the Zodiac of the primitive times was repreſented by two Kids.

Leo repreſents the ſcorching heat of the Sun in July; Virgo ſignifies the gleaning Virgin; Libra the Equinox; Scorpio characteriſtic of autumnal Diſeaſes; Aquarius the rainy Seaſons; Piſces, when Fiſh moſt in ſeaſon.

It has been ſaid the ancients had only eleven ſigns, that Libra has ſince been added. Virgil, in compliment to Julius Cæſar, aſks him where he would chuſe to fix himſelf in his heavenly condition, mentions the Scorpion occupying two places, &c. So Ovid, when deſcribing the terrified ſituation of Phaëton, when he arrives at this part,

" Eſt Locus, in geminos ubi brachia concavat arcus,
" Scorpioſi & Cauda, flexiſque utrinque lacertis,
" Porrigit in ſpatium ſignorum membra duorum."

 Virgil

Number of Stars.

PTOLEMY tells us that Hipparchus, the Rhodian, enumerated 1026; Bayer gave a liſt of 1160; Hevelius 1888; Flamſtead 3000 Stars; Antonia de Rheita counted in the Conſtellation of Orion above 2000 Stars. Dr. Herſchel's powerful teleſcope diſcovered 44,000 in the ſpace of a few degrees, which from proportion ſeem to indicate 75 millions in the Heavens.

According to the account of Hevelius, Caſſini, and others, the Stars are not immutable, ſome new ones appear and others vaniſh.

The fixed Stars are each Suns, probably illuminating their reſpective Planets as our Sun: it is ſuppoſed that theſe Suns, attended by all their Planets, have a general motion.

The Diſtance of the Fixed Stars.

THE moſt conſpicuous is Sirius: yet the Earth in moving round the Sun is at one time 198 mil-

Virgil in another part mentions Libra,

"Libra Diê ſomnique pares ubi fecent horas,
"Et medium luci atque umbris jam dividet Orbem."

And Horace mentions them both,

"Seu Libra, ſeu me Scorpius aſpicit."

lions

lions of miles nearer than at another, yet the magnitude of the Star does not appear the leaſt altered.

To aſcertain the diſtance, Gregory ſuppoſed Sirius to be of the ſame bigneſs with the Sun, and to have the ſame apparent diameter as Jupiter in Oppoſition. Huygens ſays their diameters cannot be meaſured, as being only lucid points; he adopted another mode, by which he aſcertained it to be 27,664* times farther than the Sun. Caſſini's method was equally hypothetical, who only made it 384 times as far as the Sun.

This has been more accurately determined by the great diſcovery of Dr. Bradley, on the Theory of the Light's Motion; his obſervations were made on a Star in the Head of Draco to be 10,210 times greater than the diameter of the Earth's Orbit, by a theory now called by aſtronomers

The Aberration of Light.†

* Huygens covered one end of a twelve foot empty tube with a very thin plate of braſs, wherein he had pierced a very ſmall hole, not exceeding the 140th part of an inch, which reduced the Sun to 182d part of his whole diameter; he appeared much brighter than Sirius: a ſmall globule of glaſs of the ſame ſize of the hole was put in, and which reduced it to the 152d part of 182, equal to 27,664.

† Aberration of Light. Ricciolus and others objecting to the Copernican ſyſtem, that if the Earth moved in an an-

 nual

nual Orbit round the Sun, there would be a difference obſerved in the meridian altitude of a fixed Star, in the ſame place of obſervation at different ſeaſons, called the Earth's Annual Parallax, being that angle under which the diameter of the Earth's Orbit would be ſeen from that Star, if this bore any proportion.

Dr. Hooke, to determine this, directed his teleſcope, fixed in the roof of his houſe, of 36 feet, to the bright Star in the Head of Draco, which paſſeth nearly over the vertex of London: the angle he determined to be 27 or 30 ſeconds, about 17,000 times as far off as the Sun. Flamſtead found this incorrect: in order to have a ſecure building, he fixed the arch of a circle to a ſtrong wall at Greenwich, now called the Mural Arch, and found it after 7 years, 40 or 45 ſeconds.

The inſtrument was no ways accurate. In 1725 Dr. Bradley made uſe of one made by Graham; the reſult of many obſervations were, that the Star appeared more northerly in December than in June, contrary way to what it ought to be from the annual parallax. Dr. Bradley concluded this to ariſe from the progreſſive motion of Light. This angle he found to be about 30 ſeconds, and which is in proportion to the angle at the Baſe as 1 to 10,799; ſo that the motion of Light is ſo many times greater than that of our Earth, and the diſtance of the Star 10,799 times the diameter of the Earth's Orbit, viz. 2033408000000 miles.

ADDENDA.

ADDENDA.

As the explanation on mechanical principles of thoſe experiments which are generally adduced to demonſtrate the exiſtence of certain active powers, as *Attraction* and *Repulſion*, had been fully given in a volume of Philoſophical Eſſays lately publiſhed; in the Analyſis reference has been given to this work: the Author underſtands from the Printer that there are not many Copies left, on which account he has thought proper to tranſcribe from the aforementioned work, what peculiarly relates to theſe experiments.

EXPERIMENT I. *The tendency of light Bodies floating on the ſurface of Water contained in a veſſel, towards the ſides of that veſſel.*

When a glaſs veſſel is nearly filled with water, a thin glaſs bubble, or a piece of cork, placed on the ſurface, moves with an accelerated force towards the ſide of the veſſel.

In floating a body which is ſpecifically heavier than water, but whoſe gravity is not ſufficient to overcome the combinatory union of the particles of

of water, as a needle ſwimming on water, a contrary effect is obſerved; the needle avoids the ſides of the glaſs, and tends towards the centre.

If the glaſs veſſel be filled to the utmoſt with water, theſe effects are reverſed; the glaſs bubble flies from the edges, and moves with rapidity towards the middle; the floating needle in this caſe does not retain its central ſituation, but moves with an increaſing velocity towards the ſides.

In either caſe, a large ſolid ſtick of glaſs no ways influences the bubble or needle, however near applied, unleſs the ſtick touches the water.

Theſe effects are the neceſſary reſults of the fluid varying in its height.

In a half filled glaſs, the fluid is higheſt in that part where it is in contact with the glaſs, and loweſt in the centre; as bodies ſpecifically lighter than the fluid on which they float, muſt riſe to the ſuperior part, the cork or glaſs bubble will from hence approach the ſides of the veſſel, while a needle being ſpecifically heavier, will deſcend to the loweſt part.

Thus melted lead, when left to cool in a veſſel, has always a depreſſion towards the centre.

When a glaſs is more than filled, the water is higheſt in the centre, and loweſt towards the edge; in this caſe the ſpecifically lighter body will move towards the centre, and the heavier one towards the circumference.

Fluids

Fluids move in that direction where they meet with the leaſt reſiſtance; a fluid confined in a veſſel tending towards the centre of the Earth, meets with leſs reſiſtance in its central portion, than in that part where in contact with the ſolid body, which limiting the preſſing action of the whole fluid, renders it the higheſt in the circumference.

When a veſſel is more than filled, the edge of the fluid is in contact with Air, where it meets with leſs reſiſtance than in its central portion, in this caſe the fluid hangs over the edge of the veſſel, the gravity of the fluid not overcoming the combinatory union of the particles of water; hence the circumference will be the loweſt.

The Riſe of Fluids in Capillary Tubes.

When a tube of a ſmall bore is immerſed in water, the fluid riſes to a certain height above the level. If a tube twelve inches long, and whoſe bore does not exceed the twentieth part of an inch, be divided into twelve parts, when one part is immerſed in the fluid, the water riſes near one inch and a half in the tube above the level; when two parts of the tube are immerſed, the aſcent is about one inch and a quarter; when three parts are immerſed, the difference is ſtill leſs; when ten parts are immerſed, the riſe is not more than a quarter of an inch; when the whole tube is immerſed, the aſcent is nothing.

If the ſides of the tube cauſed the fluid to riſe by virtue of any attractive power, why ſhould there be this gradation in the aſcent of the fluid?

Theſe effects ariſe from the different elaſticity of the Air; the elaſticity of the Air is always a counteracting balance to the general preſſure of the Atmoſphere: as a diſtended bladder preſerves its diſtenſion, becauſe the elaſticity of the included Air is equal to the preſſure externally. As the elaſticity of the Air is the action and reaction of its conſtituent particles in a minute column, there cannot be the ſame elaſticity as in the ſurrounding unconfined Air. When the tube is immerſed in the water, the preſſure of the outer Air will cauſe the water to riſe; when the tube has more of its parts immerſed, then the aſcent is not ſo great, becauſe the Air in the tube out of the water being nearer the Atmoſpheric maſs, neceſſarily increaſes in its elaſticity, and proportionably reſiſts the riſe of the water; this reſiſtance increaſes the leſs portion of the tube there is out of the water, till ultimately the reſiſtance is equal to the atmoſpheric preſſure.

A fluid will riſe to a certain degree, when the upper end of the tube is not open; alſo an electrical ſpark will ſtrike a conducting body at a greater diſtance thro' a ſmall tube, than thro' the open Air.

It may be objected to this, that the fluid will riſe in tubes placed within an exhauſted receiver; in the imperfect manner a receiver is exhauſted, the

ratio

ratio of the elaſticity of the Air in the tube to that of the receiver will be the ſame as above.

The Force with which two poliſhed leaden Hemiſpheres cohere.

When two poliſhed leaden, or other ſoft metallic Hemiſpheres are rubbed together with a rotary motion, they cohere with ſuch power as to require a weight for their ſeparation conſiderably more than what would be requiſite for the ſeparation of exhauſted Magdebourg Hemiſpheres of the ſame ſize. Two leaden Hemiſpheres, of about an inch and a quarter in diameter, will require 150lb. to ſeparate them.

When the planes are placed upon each other, and preſſed with ever ſo great a weight, there is no cohesion produced. No ſuch effect is induced by the application in any mode of braſs or iron Hemiſpheres. When a leaden Hemiſphere is examined after the coheſion has been produced, the ſurface appears covered with ſpiral lines and ridges, where particles of the lead are raiſed up.

From this circumſtance the power with which they unite is eaſily explained.

The reverſe rotary motion round the axis of each Hemiſphere raiſes up on each plane particles of the lead in contrary directions, ſo that all the particles of the one being locked with thoſe of the other, will reſiſt ſeparation in proportion to the number of particles thus entangled. However ſtrong the

Hemiſ-

Hemiſpheres are united, they do not in the leaſt reſiſt the ſame rotary motion which induced the union. When the Hemiſpheres have thus been uſed two or three times, the ſurfaces become ſo irregular, that no union can be induced till the ſurfaces are ſcraped.

Theſe circumſtances, which have been adduced as proofs of the exiſtence of certain powers, are reducible to pure mechanical principles; ſo alſo Gravitation, Optics, Electricity, and the Doctrine of the Tides, have been ſimilarly explained in the foregoing Analyſis, as copiouſly as the limits of ſuch outlines will admit. Theſe *Powers*, as well as the nature of a *Vacuum*, the Author has preſumed to reject in this Syſtem of Philoſophy; he is in hopes that the ground-work will be clear and evident, when the fundamental principles are cognizable to every mind. When he firſt commenced the ſtudy of philoſophy, he found himſelf embarraſſed by crouds of *Powers*, *ætherial Atmoſpheres*, *attractive and repulſive Influences*, &c. not being enabled to conceive their exiſtence, he felt himſelf diſcouraged in his purſuits, and attributed to his own inability, what he now finds incomprehenſible to all.

If by any exertions of his the ſtudy of Philoſophy ſhould any ways be facilitated, if by any explanation he has attempted, the fundamental principles ſhould be eaſier comprehended, his purpoſe will be fully anſwered.

ELEC-

ELECTRICITY.

The Eſſay on Electricity has been publiſhed ſome time; as it contains the outlines of the Lectures on this Branch of Natural Philoſophy, it has been thought adviſeable to annex it to the Analyſis inſtead of reprinting it. In additional confirmation of the Theory there advanced, the Author begs leave to add the following remarks.

Pith balls placed under a receiver exhauſted of Air to its greateſt degree, do not diverge on the application of Electricity.

In condenſing Air, in an inſulated braſs ball on which are ſuſpended two pith balls, on the firſt condenſation the balls diverge with poſitive Electricity; on continuing the condenſation, caloric is then given out: when the Air is diſengaged, the balls diverge with negative Electricity. Caloric is abſtracted from ſurrounding bodies, a conſiderable degree of cold is induced.

A lighted taper placed between two balls of an univerſal diſcharger, the flame will be in an oppoſite direction to that ball which communicates with the poſitive ſide of the Leyden Jar.

A Leyden Phial placed under an exhauſted receiver cannot be charged; even when charged, as the exhauſtion goes on, the Electricity equalizes itſelf. When two Atmoſpheres are condenſed into the

the ſpace of one Atmoſphere, the charge of the Leyden Phial is proportionally increaſed.

Cuthbertſon's Electrometer, in its action ſimilar to Brooks, in the form of a balance, the end communicating with the poſitive ſide of the Jar a few grains heavier than the other arm, underneath which is placed a ſliding rod with a ball, communicating to the negative ſide. The intenſity of the charge will be meaſured by the diſtance between the ball of the ſliding rod and the ball of that arm of the balance which is not connected with the poſitive ſide of the Jar.

As the Jar is charging, the balance participates of the intenſity; in this ſtate poſſeſſes more than the ſurrounding Air, the Air acted upon by this ſurcharge, reacts on the ball; that portion of Air between the two balls reacts leſs than the Air above the ball, owing to the action of the Electricity in the balance, cauſing the Air placed between it and the ball of the ſliding rod to unload itſelf of an adequate quantity of Electricity; ſo that the reaction of the Air above the ball being greater than from that below, the ball is preſſed downwards, and the diſcharge takes place. As the reſiſtance to overcome is in proportion to the diſtance, this becomes a meaſure of the intenſity.

F I N I S.